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Technical Report

FINAL REPORT OF THE USAKA LONG RANGE PLANNING STUDY

R.E. SAMPSON

MARCH 1990

US Army Strategic Defense Command
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TABLE OF CONTENTS

1.0	INTRODUCTION.....	1
2.0	SUMMARY.....	5
3.0	USAKA MISSION AREAS AND CURRENT MEASUREMENT CAPABILITIES.....	9
3.1	MISSIONS.....	9
3.2	INSTRUMENTATION SYSTEMS.....	11
3.3	METRIC MEASUREMENTS.....	15
3.4	SIGNATURE MEASUREMENTS.....	17
4.0	USER NEEDS AND SHORTFALLS.....	19
4.1	USER NEEDS.....	20
4.2	SHORTFALLS.....	21
5.0	SYSTEM MODIFICATIONS.....	25
6.0	NEW SYSTEMS.....	31
7.0	SYSTEMS REQUIRING INVESTIGATION AND DEVELOPMENT.....	35
7.1	STUDY TO ESTABLISH DEVELOPMENT OF A COMPREHENSIVE OPTICAL MEASUREMENT CAPABILITY.....	35
7.2	STUDY TO INVESTIGATE ALTERNATIVE LONG RANGE HIGH QUALITY METRIC MEASUREMENT CAPABILITIES.....	37
7.3	INVESTIGATION OF SYSTEMS SUITABLE FOR IMPACT SCORING.....	40
8.0	CONCLUSIONS AND RECOMMENDATIONS.....	43
9.0	REFERENCES.....	47
APPENDIX A.	USER NEEDS FOR UNITED STATES ARMY KWAJALEIN ATOLL (USAKA) DATA.....	49
APPENDIX B.	STEERING GROUP MEMBERS.....	137
APPENDIX C.	STUDY GROUP PARTICIPANTS.....	139
APPENDIX D.	OPTICS STUDIES.....	141

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LIST OF FIGURES

Figure 1. Implementation of New Capabilities..... 7

Figure 2. Optical Needs and Capabilities..... 24

LIST OF TABLES

Table 1. System Modifications..... 28

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Project guidance and direction was provided by Dr. Peter Pappas and Mr. Stuart Fields of USASDC and the steering group members listed in Appendix B. Their assistance and advice during the various stages of this study are gratefully acknowledged.

1.0 INTRODUCTION

The United States Army Kwajalein Atoll (USAKA) is the reentry end of the Western Test Range. Equipment and facilities located there include radars of UHF, VHF, S, L, C, X, Ka and W bands, telemetry recording systems, and high resolution visible optics systems. These systems were designed to track and record metric and signature information on reentering objects primarily in support of US offensive systems development and readiness evaluation. The evolution of SDI programs to the testing phase is expanding the previous role and creating a new role in evaluation of defensive system components and concepts; the expanded data collection requirements at Kwajalein include real time discrimination, intercept monitoring, and relative distance measurements between very high speed objects. Data is needed at longer ranges, on more objects, and at wavelengths other than those that have been required in the past.

A second area of increasing demand for measurements at Kwajalein involves space surveillance and monitoring of foreign launches and activities. These are natural applications for the high power long range, well situated radars located at Kwajalein.

The objective of the study described herein was to develop a long range plan for ensuring an orderly evolution of instrumentation and capabilities at Kwajalein for meeting future changing needs. The methodology to accomplish this objective consisted of first assessing User Needs by meeting with present and anticipated future users and determining their data needs for the foreseeable future. The results of these meetings are summarized in the "User Needs Study Report" [Reference 1]. This summary focused on the details of the data required by users and not on the uses of the data collected. Therefore, we supplemented these needs with some additional information from researchers and developers in the field in order to

completely represent future needs. A description of the uses of data from Kwajalein and missions that the facilities at Kwajalein need to support is included as Appendix A.

The second phase of the study assessed current systems capabilities and defined shortfalls as being any discrepancies between capabilities and stated user needs. The results of this analysis were reported in a separate report "Current Systems Deficiencies Report" [Reference 2].

Next, three categories of solutions for alleviating these shortfalls were identified and analyzed. The first category consists of modifications to existing systems over and above those modifications that are currently underway. These are reported in a separate report "Existing Systems Modifications" [Reference 3]. This report summarizes modifications not currently funded that would alleviate some of the shortfalls. There are currently modifications in progress that address some of the shortfalls identified in Reference 2, and which are documented in Reference 3, but are assumed to represent part of the baseline capability.

Lastly, the two remaining categories of 1) new systems and 2) system concepts requiring investigation and development, were identified and analyzed. These are discussed in the fourth report from this study entitled "New Systems and Research Activities Report," [Reference 4].

Direction for the study was provided by the Advisory Group (Appendix B) under the direction of Dr. Peter Pappas. Study participants included technical personnel from five organizations under the direction of Mr. Stuart Fields of USAKA (Appendix C).

This final report will summarize the highlights from these study reports and present an overview of future USAKA direction. The detailed discussions are contained in the individual study reports [References 1-4] and the reader is referred to them for additional information.

The remainder of this report is organized as follows. Section 2 contains a summary of the major study results and planned future

capabilities. Section 3 summarizes USAKA missions and existing instrumentation and measurement capabilities. Sections 4 through 7 summarize the four phases of this study (1. review of user needs, 2. documentation of current capabilities and determination of shortfalls, 3. determination of system modifications, and 4. analysis of new systems and future research activities). Section 8 contains the study conclusions and recommendations.

2.0 SUMMARY

This study surveyed and documented the data requirements for USAKA as stated by the users [Reference 1], examined current capabilities and shortfalls in these capabilities and the stated user needs [Reference 2], defined system modifications needed in the near term to address these shortfalls [Reference 3], and examined new systems and research activities [Reference 4] needed to meet shortfalls beyond the current system capabilities. The key results from this activity can be summarized by the following points.

- Current range instrumentation is focused on well developed and sophisticated radar systems. There is limited capability in optical systems beyond reentry phase metrics and photodocumentation.
- The next five years will bring increased demand for optical signature data (both midcourse and reentry), metric data requirements on more sophisticated target complexes at longer ranges, and more intercept tests and measurements for strategic defense and discrimination studies.
- In this same time period, several new experimental sensor systems will become available. Some of these are expected to become available as range instrumentation (GBR-X), some will be partially available to the range (OAMP), and other have no planned association with the range (MSX) but offer very useful and needed capability. The range must monitor and review these system capabilities as they evolve in order to maximize their utility for future range users.
- Several existing system modifications and upgrades are necessary in order to ensure the range is able to reliably

respond to user needs. A prioritized list has been developed and included in this report.

- The new systems and modifications to existing systems described above will not be adequate to satisfy all projected user needs. Three research investigations to study potential solutions to remaining shortfalls are proposed.

The timing of the implementation of the major categories of modifications and the new systems and research activities are shown in Figure 1. These activities will significantly increase the capabilities available to USAKA range users and facilitate the timely and efficient provision of data products.

This enhanced capability will require active range personnel involvement. The specific activities and the time frames involved are as follows.

March 1990 - August 1990

Conduct a short study to identify the most cost effective option for satisfying impact scoring needs. Systems with multiple users and new planned systems should be examined carefully before a dedicated system is selected.

March 1990 - February 1991

Initiate a government-wide analysis of infrared and optical missile test measurement needs in order to define an integrated, comprehensive optical measurement system. Monitor OAMP data collection experience at USAKA to obtain additional data on the utility of aircraft platforms.

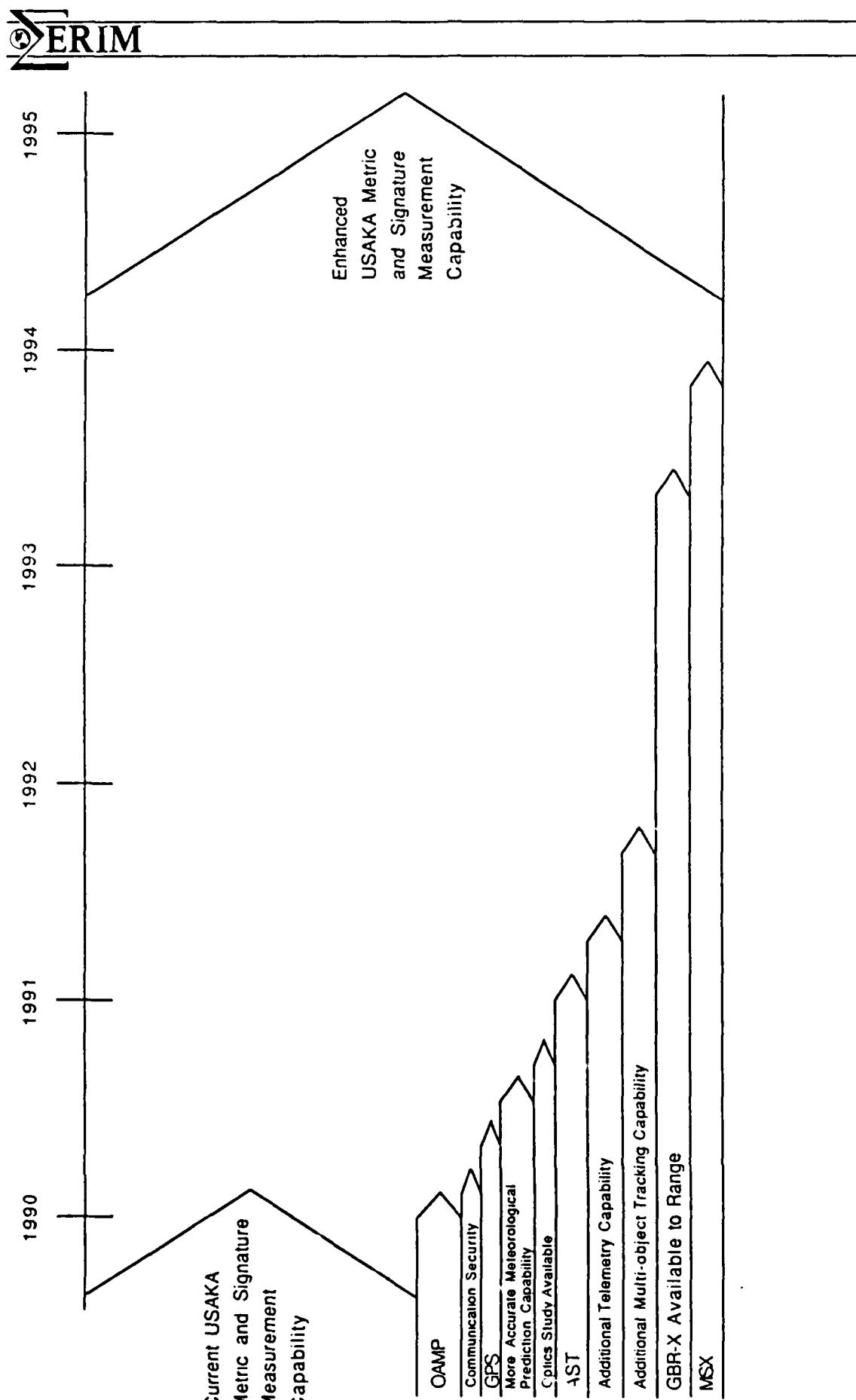


Figure 1. Implementation of New Capabilities



March 1990 - September 1992

Monitor GBR-X design reviews, participate with GBR-X program office in defining tasks required for transition. Conduct tasks required for transition and develop software needed to integrate GBR-X into range sensor network.

March 1990 - March 1991

Monitor GFS development and utilization. Assess user willingness to install translators on targets. Conduct detailed analysis of multi-lateration system and its capability and utility.

March 1990 - October 1993

Monitor MSX sensor development and encounter (orbit) characteristics as system design progresses through final design stages and construction. Define communication capabilities required to interface with Kwajalein. Assess feasibility of utilizing system for satisfying midcourse portion of USAKA test range users optical data needs.

October 1990 - October 1991

Monitor AST data collection experience measurements Assess adequacy of platform and sensor for satisfying some user optical data needs.

3.0 USAKA MISSION AREAS AND CURRENT MEASUREMENT CAPABILITIES

3.1 MISSIONS

USAKA is the terminus of an array of US facilities beginning on the West coast, including facilities on the various Hawaiian Islands and potentially on smaller islands such as Wake, Midway and Johnston Islands and also potentially in orbit. This array of facilities is used for three main data collection purposes:

- Developmental testing of advanced offensive ballistic missile systems and components,
- Confidence assessment of existing operational ballistic missile systems, and
- Research on and developmental testing of strategic defense systems and their components.

Additionally, USAKA facilities are used to study orbital objects. The principal roles of USAKA's data collection requirements are as follows:

- The most fundamental role is to provide information that can be used to determine what happened in a test. The data to be provided can, however, span a very broad range of complexity, ranging from trajectory and impact determination to the validation of performance of decoys. It can be anticipated that new requirements will commonly originate from a single user, especially SDIO, but, if offensive technology advances, spread to other users.

- A second major role is to provide surrogate information in the testing of strategic defense system components and concepts, i.e., surrogate for either the "real" (or prototype) sensor or for the real target. Again, this can range from providing relatively simple tracking data to performing complex discrimination tasks which would ordinarily be provided or performed within the ABM system itself.
- A third major role is to acquire data supporting the development of ABM system components (or their defining requirements). As an example, the GBR-X is certainly not identical to any of the KREMS radars, but much of the data and experience needed for its specification was obtained with the KREMS radars.
- The final missile range sensor function is a supporting function namely to monitor (and support prediction of) the missile range meteorological environment and to monitor safety.
- The USAKA sensors have the additional function of studying orbital objects and Soviet ballistic missiles fired into or over the area.

Potential changes in the users of the USAKA facilities include an expanded intelligence role for monitoring foreign launches and space surveillance, an expanded role as a test bed for simulating foreign sensors, and as a testing facility for ASAT, DEW or Cruise missiles. An additional role which may become more important in the future is as a special target imaging and signature measurement facility.

3.2 INSTRUMENTATION SYSTEMS

USAKA capabilities include long range tracking and signature radars, a variety of optical instruments and cameras, impact scoring systems, and supporting services including telemetry and meteorological measurement capabilities. These systems are used for both metric measurements (target tracking, location determination, and target microdynamics) and signature measurements (amplitude and spectral characteristics) for the missions discussed in Section 3.1. Metric and signature measurements required are discussed in sections 3.3 and 3.4.

3.2.1 Radar Resources

USAKA radar systems, which are part of the USAKA data acquisition system, are primarily located at the Kiernan Reentry Measurement Site (KREMS). The KREMS sensors are all located on Roi-Namur Island, and consist of the ARPA-Lincoln C-Band Observables Radar (ALCOR), the ARPA-Long Range Tracking and Instrumentation Radar (ALTAIR), the Target Resolution and Discrimination Experiment (TRADEX) radar, and the Millimeter Wave Radar (MMW). The other USAKA data acquisition radars are the AN/FPQ-19 located on Kwajalein island, and AN/MPS-36's located on Kwajalein and Illeginni.

The radars located on Roi-Namur are under the direction of the KREMS Control Center (KCC) also located on Roi-Namur and support both reentry and space track missions. KCC is under the direction of the Range Operations Control Center (ROCC), located on Kwajalein, which is in direct contact with Honolulu and the range user. ROCC also maintains constant contact with the Range Safety Center (RSC) during all mission activities. When ALTAIR is not supporting USAKA missions, the deep space surveillance radar responds directly to the Air Force 24 hrs/day, 7 days/week.

During a reentry mission, ALTAIR is often used to initially detect incoming vehicles, and the other sensors are initially slaved to

ALTAIR via the KCC data bus. Later, the other sensors may be slaved to ALCOR which will provide pointing vectors to different vehicles based upon beacon track information. ALCOR and MMW may also be used to discriminate targets when beacon tracks are not part of the mission profile.

3.2.2 Visible Optical Resources

Precise photographic instrumentation data on missile performance is provided for support of Range operations by tracking camera stations, ballistic cameras, and special fixed cameras. The tropical conditions common to this area favor employment of photo-instrumentation because of brilliant lighting and strong shadow contrast. However, visibility is generally reduced between the surface and +15 degrees by drifting cumulus clouds. This impedes the ground based acquisition of optical data on incoming vehicles impacting in the broad ocean area at significant distances from the islands in the Atoll.

The principal metric measurements supported by the USAKA optical sensors are those related to trajectory estimation. The complete specification of a vehicle trajectory requires measurements of range, elevation and azimuth, each as a function of time. The current optical sensors provide only the latter two quantities, but with the greatest precision and accuracy (approx. 25 microradians) of all the USAKA sensors. The other significant metric measurement that is possible with the USAKA optical sensors is that of RV wake length. The measured angular extent of the wake must be combined with range and aspect angle data to produce an estimate of physical length.

The signature measurements supported by the current USAKA optical sensors include quantitative estimates of RV radiant intensity and qualitative spectral analysis of that intensity. Both measurements are limited to roughly the visible spectrum (380-690 nanometers).

Tracking camera systems consist of Recording Automatic Digital Optical Trackers (RADOTs) and Super RADOTs. Fixed camera systems

include the Ballistic Plate Cameras (BC4s), the Spectral Ballistic Plate Cameras (SBCs), and a mix of Motion Picture (MOPIC) and video cameras located on Fixed-Camera towers and mobile units.

3.2.3 Scoring Systems

Scoring systems are used to provide direct measurement of the location of events, such as RV impact. They consist of Splash Detection Radars (SDRs), Hydroacoustic Impact Timing System (HITS), and Sonobuoy Missile Impact Location System (SMILS).

The SDRs are scanning radar systems specifically designed to detect the splash of a reentry vehicle as it impacts the water surface. The X-band SDR's operate at a frequency of 9.375 GHz with V-V polarization and scan an area of 360 degrees in azimuth. The radars have a clear weather capability of detecting a splash of 9 meters minimum height and three seconds minimum duration from a minimum range of 8 km to a maximum range of 30 km with a detection probability of at least 95 percent. The SDR's are located at Legan (SDR-3) and Gellinam (SDR-7) Islands. Scoring coverage is provided in the lagoon area and the broad ocean areas immediately to the east of Kwajalein Atoll and to the west of the lagoon.

The Hydroacoustic Impact Timing System (HITS) is an underwater sound detection system used to detect and record the impact of an RV on the water surface. The HITS four sensors, each composed of hydrophones and velocimeters, have been placed in storage at Kwajalein. The system has a design impact timing accuracy of +2.6 milliseconds which corresponds to an impact location of +4 meters to +6 meters for the distribution of lagoon targets covered by HITS. However, this system has not been used in over a year and recent attempts to check the instrumentation indicate it may no longer be functional. Sensor locations are west of Gellinam in the lagoon.

SMILS is an airplane-based sonobuoy floating array system dropped prior to the mission in the ocean impact area. The system is designed

to determine the time and position of missile impact in the broad ocean target areas.

3.2.4 Telemetry

USA KA range instrumentation provides capability to receive and record encrypted telemetry signals from appropriately instrumented targets.

USA KA telemetry (TM) ground stations are located on the islands of Ennylabegan (also known as Carlos), Roi-Namur, and Gagan. These locations provide a varied tracking geometry for reentry, orbital and launch operations. All three locations have single channel monopulse 2.2 to 2.3 GHz autotracking antenna systems. USA KA is currently in the process of upgrading the systems to support the new increased S-band IRIG standard bandwidth for telemetry (2.2 to 2.4 GHz).

3.2.5 Meteorological Observation and Forecasting Capabilities

The primary function of the meteorological support group at Kwajalein is weather data acquisition and forecasting in support of missile operations. In addition to scheduled meteorological support for Range Operations, general weather and aviation terminal forecasts are issued on a scheduled basis. Advisories and warnings are issued as required.

The data gathering function consists of the following: taking complete, often specialized, surface observations; making upper air soundings using rawindsondes, meteorological rockets, theodolites and wind finding radars; and tracking and recording data from meteorological satellites and radar observations. Real-time range operations support is provided by a meteorologist in the Range Operations Control Center. Specialized meteorological support is available on request to assist in describing weather criteria for meeting test objectives.

3.3 METRIC MEASUREMENTS

3.3.1 Tracking

The tracking function can be broken into two categories: skin and beacon. Most of the radars on USAKA are intended for active tracking of targets by reflecting radio emissions off of their "skin" or surface. Some of the systems (ALCOR, FPQ-19, and MPS-36), however, are capable of tracking using a radio transmitter, or "beacon", located on the target. The skin tracking function can be further divided into subcategories distinguished by the type of targets being tracked: incoming (e.g. RV) and outgoing (e.g. locally launched missiles), and New Foreign Launch (NFL) and Deep Space (DS) targets.

The principal metric measurements supported by the USAKA optical sensors are those related to trajectory reconstruction. Optimum trajectory coverage requires at least three tracking sensors per RV. Since there are six Super-RADOTs and only three RADOTs, the current range practice is to assign two Super-RADOTs and one RADOT to an RV. This implies that no more than three RVs can be optimally covered in any mission. In addition to permitting multi-lateration, redundant coverage by non-collocated sensors also precludes complete loss of data due to drifting clouds over any one sensor. This is a significant consideration given the prevailing USAKA cloud conditions.

Trajectory coverage by optical sensors is generally limited to within the atmosphere. Limited exoatmospheric tracking is possible with the Super-RADOTs, but only under specific conditions and times of day (i.e. sunlit RV observed during local nighttime). Although the optical sensors can collect data during the daytime, the much greater background (sky) illumination further reduces their effective range to well within the atmosphere. The current sensor resolutions should permit resolved imaging of an RV, at least in its later stages of flight. Such images might provide useful data on vehicle microdynamics (coning, nutation, etc.). However, the current sensor configurations result in the vehicles appearing as "blobs of light" due to saturation

effects. Thus, the additional metric potential of RV imaging is not being realized.

3.3.2 Location Determination

The location determination function requires identifying the position of a target at the occurrence of a specific event. There are three potential categories for this function: (1) locating the "pierce-point" (i.e. the position where a target enters the atmosphere); (2) locating the "impact-point" (i.e. the position where a target impacts the ground or water); and (3) locating an intercept point between an interceptor and a target. The event is usually defined in terms of a specific altitude (e.g. 0 meters for impact and 300,000 feet for the pierce point) and may be made directly or from analysis of tracking information. Locations determined from tracking information are a function of radar tracking capabilities and can be determined using cross-range position accuracy.

Besides using radar trajectory to extrapolate impact position, USAKA has the HITS, SDRs, and SMILS to directly measure water impact positions.

3.3.3 Target Microdynamics

Besides measuring target trajectories, users often require information about the motion of a target relative to some point on the target (e.g. the nosetip of an RV). This motion data is referred to as target "microdynamics" where tracking information relates to target "macrodynamics". Several USAKA radars are capable of collecting this data through range-Doppler imaging.

3.4 SIGNATURE MEASUREMENTS

3.4.1 Amplitude Characteristics

USA KA range users are often interested in the radar cross section (RCS) characteristics of targets as measured from radar sites. The signatures may be characterized by a single measure (absolute) or relative measure between two or more measurement parameters.

The signature measurements supported by the current USA KA optical sensors include estimates of RV radiant intensity. Measurements are limited to roughly the visible spectrum between 380 and 690 nanometers. The radiant intensity estimates are made via photometric (i.e. photographic density measurement) techniques from the RADOT and Super-RADOT 70 mm film data. The conversion of film density to radiant intensity is based on calibration frames containing stars of known intensity.

3.4.2 Spectral Characteristics (Optical Resources)

The spectral analysis of RV radiant intensity is made with data collected by Spectral Ballistic Cameras (SBCs). The spectral band covered is from 380 to 690 nanometers with variable resolutions of 1.33, .8 and .4 nanometers. The SBC FOV is 681 x 681 mrad. Current limitations to spectral measurements include: 1) trajectory altitudes must be below 40,000 feet, and 2) the use of photographic emulsions as the detection medium limits the dynamic range available with film saturation being common.

3.4.3 Imaging Characteristics

Images of targets is provided by both radar and optical instrumentation. Radar images based on inverse SAR techniques are available for rotating targets from both ALCOR and MMW.



Photodocumentation in the visible spectrum provides images of targets when they are in the lower part of the atmosphere and located close enough to the sensor to provide enough resolution to have multiple pixels on the target.

4.0 USER NEEDS AND SHORTFALLS

The primary users of data collected at United States Army Kwajalein Atoll (USAKA) are the DoD organizations responsible for the development and maintenance of the US offensive and defensive ballistic missile capability. Additional missile data users are the intelligence community and organizations with space satellite and object surveillance and monitoring responsibilities such as Space Command and NASA. The final category of USAKA data user includes non-missile and space object data users such as those interested in physical and atmospheric phenomena measurements (for example; the Defense Nuclear Agency and NASA).

The approach used to identify present range instrumentation shortfalls involved four basic steps: (1) identification of user needs through direct interaction with current and potential future USAKA range users; (2) description of USAKA instrumentation capabilities from information gathered via site visits, discussions with USAKA support contractors and review of instrumentation documentation; (3) development and use of common terms and formats for representing user needs and instrumentation capabilities; and (4) request for and use of specific quantitative information for the expression of needs and capabilities. The goal of our approach has been to determine user needs and range sensor requirements in quantitative/measurable terms that define both what measurement capability is needed and the frequency and number of measurements that are necessary. This approach accounted for user needs currently satisfied by existing range capabilities, and also provided the definition, in quantitative terms, of the requirements for capabilities which do not presently exist at USAKA.

4.1 USER NEEDS

Acquisition of user needs was accomplished by a series of user meetings conducted from December 1988 through March 1989. Visidyne Corporation, under contract to ERIM, collected and categorized user needs. ERIM provided Visidyne with guidelines concerning information required for each instrumentation sensor type. Follow-up questions requesting specific information from users were distributed after most of these conclaves. Details of the user needs assembled in this manner by Visidyne are contained in a separate report [Reference 1].

ERIM independently conducted discussions with management and staff members from Lincoln Labs and elsewhere to address future technology driven user needs. These needs represent a category of capabilities which are expected to arise during the next ten to fifteen years as a consequence of technology trends (such as stealth) rather than immediate or near term needs as perceived by ongoing user programs.

Activities in support of defining current USAKA instrumentation capabilities included a week long visit to the USAKA Kwajalein Atoll facilities by a team of ERIM representatives in late January 1989. Other facility visits included discussions with Aeromet in Tulsa, Oklahoma, Pan Am World Services in Huntsville, Alabama; the Data Reduction Facility in Honolulu, Hawaii; and several visits to Lincoln Laboratories in Boston, Massachusetts. Briefing materials and documentation on USAKA instrumentation and capabilities were acquired from each visit. The bulk of this documentation focussed on the radar capabilities at USAKA. Cross checking of this radar material indicated that those reference documents which were more than two years old were generally suspect in their details because of the continuous upgrading of existing capabilities. Only recent reports and information were used as references for this compilation [References 5 and 6].

A special effort was made to formulate statements of user needs in terms of output data parameters and descriptors of user experiment conditions rather than instrumentation engineering capabilities.

Frequently, the latter were specified by users based on their experience in using sensors to satisfy their information needs. We attempted to clarify such user need statements in terms of what information was needed rather than how it was to be acquired. It was our belief that this would permit a clearer picture of all user needs, and would further enhance USAKA's ability to predict and satisfy a broader range of user measurement requirements for the future. The results of this effort are contained in Appendix A.

4.2 SHORTFALLS

Shortfalls or deficiencies in current capabilities have been determined by comparing the user needs, with the existing USAKA measurement capabilities. Shortfalls are divided into three categories (major, intermediate, and minor).

Major shortfalls represent clear and significant lack of capability with respect to stated user needs. Establishment of a capability to meet major shortfalls will require substantial investment and time. Intermediate shortfalls represent definitive shortfalls which USAKA should attempt to resolve but which can likely be accomplished by modification of existing equipment or software. Minor shortfalls represent minor differences between stated user needs and current capabilities. It is recommended that these shortfalls not be fixed unless users can validate the need for the incremental advantages which would be offered by these minor improvements in capability.

4.2.1 Radar

Current radar capabilities satisfy user needs except in a few selected areas. The only major shortfall identified from explicitly stated user needs is the lack of an X-band radar measurement capability. Two other major shortfalls have been identified from a consideration of operating methods. These are:

- (1) Lack of multiple target tracking and simultaneous fine resolution imaging of all tracked targets.
- (2) Lack of capability to acquire, sort, identify and reliably hand over large target trains.

The latter need will become increasingly important in the future for operational cost efficiency as more and more tests are configured on a single launch vehicle.

As yet, user expressed needs only weakly support a need for an X-band signature radar. Several multiple target tracking and imaging needs have been expressed for the X-band frequency domain but are, for the most part, not dependent upon wavelength.

For the most part, user needs do not reflect the future need for increased radar sensitivity to accommodate potential RCS reduction which may be possible with stealth materials or coatings. Greater sensitivity will be required to simply maintain current operating ranges. Consequently, a continuing program of improvements in sensitivity for selected radars is recommended. A variety of ongoing radar upgrades are directed toward this goal.

4.2.2 Telemetry

Currently, most of the existing user needs are satisfied by the telemetry capabilities at USAKA. However, future user needs have indicated a shortfall in data reception in the area of data bit rates and recording bandwidth. In addition, there is the need for an increase in the number of tracking antennas with improved dynamics to accommodate the tracking of multiple instrumented reentry vehicles and USAKA launched interceptors.

4.2.3 Optics

There are several major shortfalls in the existing USAKA optical sensors. The lack of capability in any spectral region except the visible, as well as the disadvantages associated with sea-level platform locations removes these sensors from serious consideration with respect to satisfying user needs. Consequently, the shortfall analysis concentrated on available airborne sensor systems.

There are several airborne systems which have the capability of satisfying parts of the optical data requirements. AST and OAMP are discussed extensively in the classified report "New Systems and Research Activities Report" [Reference 4] and will not be discussed further here. These airborne platforms taken collectively cover most of the optical data needs. However, none individually have all the capability needed and they all suffer from cirrus cloud effects.

The optical needs and capabilities are summarized in Figure 2.

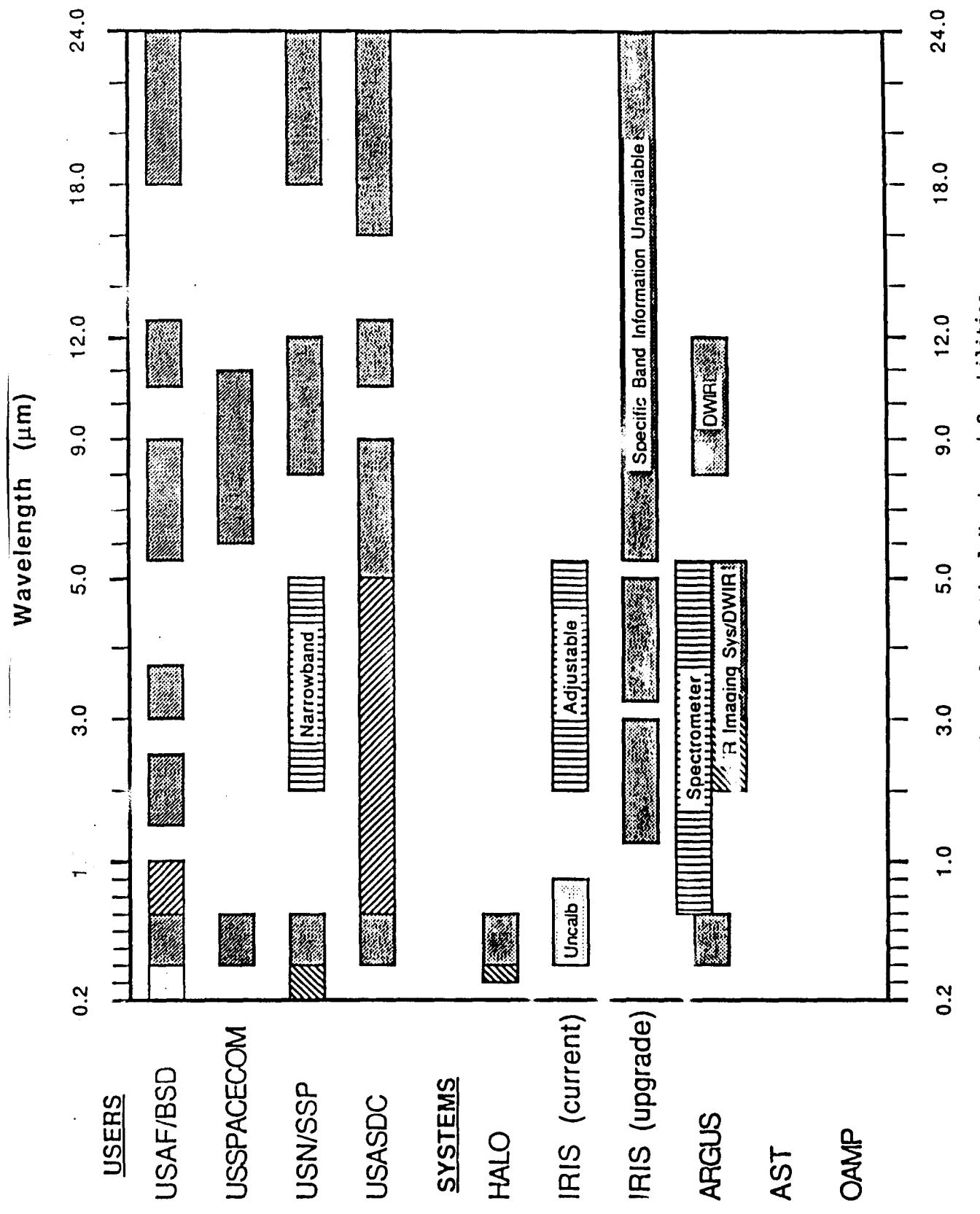


Figure 2. Optical Needs and Capabilities

5.0 SYSTEM MODIFICATIONS

Shortfalls identified from the current capabilities and Shortfalls Study (Section 4) were analyzed and those that should be resolved with existing system modifications were identified. The modifications that are needed in order to support measurement requirements at USAKA are divided into two categories. These are; 1) sensor modifications to increase measurement capability, and 2) modifications needed to support sensor measurement capabilities. The latter category consists of; 1) modifications to improve reliability and efficiency, 2) general support facility improvements, and 3) security improvements. The modifications were divided into four categories and examined in detail considering; 1) other methods or facilities capable of alleviating the shortfall, 2) reliability, 3) efficiency, and 4) cost; and a priority established. These modifications are presented in this section.

There has been no attempt to describe or justify the modifications in progress; however, it is essential to document and understand the efforts in progress in order to have a baseline for departure.

System modifications may be required due to reliability requirements, operational efficiency improvements, or user shortfalls. If a subsystem is so old it requires replacement, it is frequently logical to enhance the system capability during modification. If an enhanced capability is not integral to the modification, the system modification will not be discussed herein. This is particularly true of subsystems that require periodic replacement due to normal wear and tear. Funding for these subsystems should be included in "repair parts" of the operational and maintenance (O&M) budget.

It is assumed that the following system modifications that are currently in progress will be successfully completed:

KREMS Radars

- a. MMW Sensitivity Improvements
- b. MMW Improvements in Track Range

- c. ALCOR Computer Upgrade
- d. TRADEX Computer / Timing Upgrade
- e. New L and S Band Waveforms
- f. New TRADEX Antenna Servos
- g. TRADEX 32 Multitarget Tracker
- h. TRADEX Spacetrack Capability

Other Instrumentation

- a. Meck Communication Upgrades for ERIS
- b. GPS Support for ERIS
- c. MaST Ellipticity of the MPS-36 on Illeginni
- d. KRSS Upgrades
- e. TM S-Band Antenna Feed Modification (Limited)
- f. Meck Optics, Timing and TM Upgrade for ERIS
- g. C5CS ICC and ROCC Replacement
- h. Weather Satellite Automated Data Handling System
utilizing McIDAS

In order to establish the USAKA Technical Capability Baseline relative to the USAKA Instrumentation Manual it is necessary to define the status of the Hydroacoustic Impact Timing System (HITS) and the Splash Detection Radars. HITS was operational in the Kwajalein lagoon for many years and then put on inactive status by removing the hydrophones and velocimeters. Recently, upon reactivation of the system, it was concluded that the in-water components had deteriorated to such a point that HITS is no longer available and a complete new system is required. Similarly, the SDR's have exceeded their life expectancy with no source of major repair parts. Therefore, no system modifications to the SDR's are recommended until a complete analysis of the scoring requirements/capabilities can be completed. Any USAKA scoring or impact timing systems will be considered a new system and not a modification to the existing systems.

The establishment of a prioritization of potential system modifications is difficult because of the variety of systems required

at USAKA, changing test requirements, and evolving system status. For example, modifications that are designed to improve system reliability can become critical as system performance starts to deteriorate. Therefore it is expected that the priorities given to system modifications need to be periodically reviewed as system experience indicates a change in operational status of various components.

Because this study was driven by an assessment of sensor capabilities to meet user needs and the role of USAKA is to provide data and information to users, modifications to enhance sensor capabilities were established as one category of modifications for prioritization. A second category of support modifications of activities necessary to maintain measurement capabilities and support new tests was also established. These are identified as two separate requirements and prioritization done within each category.

The most immediate and universal need from the User Needs study was the need for optical data measurement capability. The available platforms for obtaining this data are all airborne and all are vulnerable to cloud obscuration. Therefore more accurate meteorological predictions will be necessary in order to utilize the optical instruments and platforms. For this reason accurate meteorological prediction capability becomes a very important asset for satisfying this user need. Thus, improving the meteorological prediction capability through the use of LIDAR and improved modeling capability are required at Kwajalein.

Another important need from the User Needs survey is the need for multiple object tracking capability. Therefore, the modifications to provide this capability are also of very high priority. Modifications to the FPQ-19, TRADEX and ALTAIR are given very high ratings, ordered by cost. These are rated higher than the improved meteorological prediction capability because they directly provide a response to a user need whereas the meteorological improvements only support a measurement capability which must be provided by new high priority sensing capability.

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Additional telemetry capability was stated by the users as needed for future tests and resulted in modifications to provide upgrades to this capability is also a high priority.

Following these high priority items based on user needs, some reliability, and efficiency improvement items received high priority because of their importance for maintaining the test range capability and their relatively low cost. Cost becomes an important consideration for the more expensive modifications because ten (10) \$800K projects can be done for the price of one \$8M project.

It should again be emphasized that this was a user needs based sensor study. Therefore considerations needed for range operations such as communications and security improvements receive consideration as they effect sensor data handling. Also, some modifications which have major reliability implications will move up in priority as the existing system deteriorates. Therefore these priorities are dynamic rather than static.

The specific modifications designed to provide additional sensor measurement capabilities are listed in Table 1. The modifications needed to support sensor measurements capability are listed in three categories in Table 2.

Table 1. Sensor Modifications to Provide an Increase
in Measurement Capability

<u>Priority</u>	<u>Modification</u>	<u>Cost</u>	<u>Months to Implement</u>	<u>Primary Driver</u>
1	FPQ-19 Logarithmic IF Amplifier	\$ 50K	10	User Needs
2	TRADEX Improved Real-Time Integration	\$ 400K	12	User Needs
3	ALTAIR Auto Acquisition of Multi-Objects	\$1000K	24	User Needs
4	ALTAIR DTSP Replacement	\$ 50K	12	User Needs

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5	FPQ-19 Optics Enhancement	\$ 690K	8	User Needs
6	LIDAR for HARP	\$ 450K	12	User Needs
7	TM Antenna Feed System Upgrade	\$ 410K	12	User Needs
8	TM Receiver and Combiner Replacement	\$1750K	12	User Needs
9	Weather Sensor	\$ 800K	18	User Needs
10	ALTAIR (FSS)	\$ 100K	10	User Needs & Reliability
11	FPQ-19 Parametric Amplifier Replacement	\$ 80K	8	User Needs & Efficiency Improvement
12	MMW All-Range Narrowband Window	\$ 150K	12	User Needs
13	MMW-2 GHz Bandwidth at 35 GHz	\$ 800K	18	User Needs
14	MMW Simultaneous 35 & 95 GHz Transmission	\$ 100K	12	User Needs
15	ALCOR Real-Time Coherent Integration	\$ 500K	12	User Needs & Reliability
16	FPQ-19 RWAS	\$ 400K	18	User Needs
17	FPQ-19 Range Machine Upgrade	\$ 440K	12	User Needs
18	MPS-36 Optics Upgrade	\$ 700K	18	User Needs
19	TRADEX S-Band Refurbishment	\$2M-25M	24-60	User Needs & Reliability
20	MMW 20 dB Sensitivity Enhancement at 95 GHz	\$1200	14	User Needs
21	MMW C-Band Beacon Tracker	\$7000	30	User Needs

Table 2. Sensor Support Modifications

<u>Priority</u>	<u>Modification</u>	<u>Cost</u>	<u>Months to Implement</u>	<u>Primary Driver</u>
A. Sensor Reliability and Efficiency Improvement Modifications				
1	KCC-Automated Target Identification	\$1000K	48	User Needs & Reliability
2	Programmable Data Switch	\$ 500K	14	User Needs & Efficiency Improvement
3	C ⁵ CS User Capability	\$ 250K	3	Efficiency Improvement
4	ALTAIR Vax Replacement	\$1500K	12	Reliability
5	FPQ-19 Computer Upgrade	\$1100K	36	Reliability
6	MPS-36 Computer Upgrade	\$1640K	42	Reliability
7	C ⁵ CS System Completion	\$ 750K	14	Efficiency Improvement
8	MPS-36 Feed & Receiver Replacement	\$2000	36	User Needs & Reliability
B. General Facility Capability Improvements				
1	NOWCAST	\$ 400K	12	User Needs
2	Film to Video Conversion	\$1460K	13	Efficiency Improvement
3	Telephone System Expansion	\$ 250	4	Reliability & Efficiency
C. Security Improvements				
1	DMS Bulk and Voice Encryption	\$ 810K	3	User Security
2	Inter Island Undersea Fiber Optics System	\$8100K	48	User Needs & Security
3	FCA Van Upgrade	\$ 345K	12	Reliability & Security

6.0 NEW SYSTEMS

New systems that have the potential for alleviating shortfalls that could not be alleviated with modifications to existing systems were identified and investigated.

There are five major new systems that have the potential to become effective range assets at USAKA. The modifier "effective" is used because, unlike existing range assets, many of these systems would not be physically located at USAKA except during range missions. The five systems addressed in this section are as follows:

1. Airborne Surveillance Testbed (AST)
2. Global Positioning System (GPS)
3. Ground Based Radar (GBR-X)
4. Midcourse Space Experiment (MSX)
5. Optical Airborne Measurement System (OAMP)

These systems, AST, GPS, GBR-X, MSX, and OAMP, may be considered to exist (i.e., are funded) in some form, although most of these are still in either the developmental or testing and evaluation phases.

In all, the five systems represent available solutions, although not always optimal ones, to several of the USAKA capability shortfalls identified in a previous report [Reference 2]. The specific shortfalls addressed by the various systems are identified below:

- A. MWIR optical capability (AST)
- B. LWIR optical capability (AST, MSX, OAMP)
- C. LLWIR optical capability (MSX, OAMP)
- D. Metric capability for >3 objects (GPS, GBR-X)
- E. X-Band radar signatures (GBR-X)

Three of the five systems, AST, MSX, and OAMP, represent partial solutions to USAKA's lack of IR optical capability. It should be

noted that no single one of these systems covers all of the IR spectral regions needed by USAKA data users. AST covers the MWIR and LWIR, while MSX and OAMP cover LWIR and LLWIR. These spectral regions are not adequately covered by any of the existing IR sensor systems (i.e., HALO, IRIS, and ARGUS) that were identified in Reference 2 [shortfall document]. (Note: Sensor upgrades are planned for the IRIS and ARGUS systems that would extend their capabilities into the mid-wave, long-wave, and long-long-wave IR regions. These upgrades are scheduled for completion in early-to-mid 1990.) All three of the new IR systems incorporate airborne or spaceborne (MSX) platforms with altitudes of at least 40,000 ft. This is necessary to avoid the atmospheric path effects that occur at lower platform altitudes.

The GBR-X phased array radar is an SDIO-funded sensor scheduled to become operational in the early 1990's. It will be located at USAKA, and so is a natural candidate to become a range asset at the end of the SDI experimental tests. It offers both X-band signature capability, which the range presently lacks, and the ability to track a large number of targets by virtue of the beam agility inherent in a phased-array radar.

The remaining system, GPS, offers the potential to obtain precise metric measurements at much greater object distances than is presently possible. This is currently being implemented at Kwajalein with ground stations to augment the satellites. This provides the capability for obtaining location for objects equipped with transponders, thus reducing the search and multi-object track problem.

These systems are at various stages of development and from various funding sources. OAMP is scheduled to be available for six tests per year at Kwajalein and is flying its initial missions; GBR-X and GPS will be physically located at Kwajalein and are at different states of development. GBR-X is completing the design phase and GPS ground stations are being installed at USAKA and surrounding islands for ERIS tests. MSX is currently planned only for dedicated missions

into Kwajalein and is currently under development. AST is still under development and its availability and utility as a range sensor is uncertain. However, all of these systems can provide unique data for users and fill shortfalls which currently exist in collection capability. It will be necessary for USAKA to be familiar in detail with these systems and their utility in order to adequately address future range user needs.

7.0 SYSTEMS REQUIRING INVESTIGATION AND DEVELOPMENT

In addition to the modifications to existing systems described in Section 5 and the new systems which are becoming available for missile data collection described in Section 6, there are three studies which are necessary in order to fully address future user needs. These are described in the following three sections.

7.1 STUDY TO ESTABLISH DEVELOPMENT OF A COMPREHENSIVE OPTICAL MEASUREMENT CAPABILITY

Existing optical observing capabilities at USAKA are limited to metric and photodocumentation applications. These inadequacies are only partially alleviated by the use of the ARGUS, HALO, Cobra Eye, and, potentially, AST systems. None of these systems, other than Cobra Eye for up to six missions a year, are part of the USAKA controlled instrumentation suite.

Specifically, the limitations of the above systems may be stated as follows:

- Lack of any MWIR exoatmospheric/early endoatmospheric signature measurement capability,
- Limited sensitivity and calibration of the HALO sensors, combined with the use of video tape as the primary recording medium, resulting in the expectation of less than signature quality data,
- Limited calibration of the ARGUS sensors, combined with the use of video tape,
- Limited availability of the Cobra Eye system as noted above,

- Uncertain availability and limited calibration of the AOA/AST system.

USAKA cannot properly support users until these deficiencies are rectified.

Capabilities for reentry measurements could be made adequate by enhancements to the ARGUS, or perhaps, the HALO systems. The primary enhancements needed are improvements in instrument calibration and use of a digital recording system. These capabilities could also, of course, be provided by development of a dedicated system independent of either the ARGUS or the HALO. In either case, the following should be recognized:

- There is a high degree of similarity between the sensor and platform requirements needed for reentry and boost phases. While a single aircraft cannot support both ends of the same mission, enough missions are flown to obtain the necessary data on both boost and reentry phases with a single aircraft. Any enhancements of ARGUS or HALO or acquisition of new sensor/platform systems to support reentry measurements should also be configured to support boost phase measurements. Any reconfiguration required between the two types of missions should be minor, such that it can be accomplished in a very few days.
- It is highly desirable that the photodocumentation sensors be placed on the same platform as the reentry sensors. There is considerable overlap in the required sensors and overall operational cost savings would be expected to offset the cost of any additional sensors. While the combination of the sensors on a single aircraft would result in a slight loss of operational flexibility, this will probably be more than offset by the operational simplicity afforded by

consolidation. The aircraft platform should be equipped with GPS as well as an INS. The INS capability should be of such a caliber as to permit metric quality data acquisition based upon the use of GPS and stellar alignment immediately before or after object measurements.

As discussed in Appendix D, no single sensor platform combination can satisfy all user requirements at USAKA or, for that matter, any other major user venue. This finding is consistent with current efforts, as the US has aircraft, probe, and satellite based L/LLWIR midcourse sensor systems either under development or in operation for exactly the reasons outlined in Appendix D. None of these sensors is intended to be dedicated to USAKA, yet all can be used in support of USAKA missions. Also, all are intended for use in support of missions at other locations.

An optical sensor study is needed to address the unresolved issues associated with platforms and sensors for optical measurements at Kwajalein. Issues which the study should address include; 1) details of data requirements and user needs, 2) availability of optical systems, 3) modifications possible to existing or underdeveloped systems, and 4) platforms suitable for use at Kwajalein. It is expected this study will cost \$400K and take one year to complete.

7.2 STUDY TO INVESTIGATE ALTERNATIVE LONG RANGE HIGH QUALITY METRIC MEASUREMENT CAPABILITIES

Metric accuracy is important to users who perform experiments and fly missions at USAKA. In missile defense system tests, interceptors will need to be directed to an area of battlespace into which the trajectory of an uprange target has been extrapolated. For the extrapolation to be useful, uprange measurements of the target's trajectory must be intrinsically accurate. Later, when interception occurs, the measurement of miss distance is a key parameter in evaluating the performance of the interceptor's homing capability.

Clearly, accurate metrics are needed not only in the vicinity of Kwajalein Atoll and into re-entry, but also far enough uprange to make handovers to interceptor systems possible.

One method of achieving accurate metrics is the use of the Global Positioning System (GPS), augmented by the installation of ground stations. For example, currently the integration of GPS instrumentation at USAKA, on several atolls near Kwajalein, and on Johnston, Midway, and Wake Islands to support the Exoatmospheric Re-entry Vehicle Interceptor Subsystem (ERIS) is in progress. GPS translators on the interceptor and on the targeted RV can then provide vectoring information in real time.

However, there are cases for which the GPS is not appropriate. The use of GPS involves the installation of antennas, batteries, and the associated electronics package on the object of interest. Such additional weight may not be acceptable to the RV designer, who must reconfigure the target (RV or decoy) to accommodate changes in the mass distribution, in the arrangement of interior componentry, or in the integrity of the heatshield.

Thus, while GPS offers many advantages to USAKA, its use is not universal. An alternative to the GPS is the use of a multi-lateration radar system that can provide accurate metrics without affecting a target's aerodynamic behavior, signature, design, or method of deployment.

Experience has shown that the existing Multistatic Measurement System (MMS) at USAKA can provide very accurate vector position, velocity, and acceleration estimates in post-mission processing. The MMS illuminator is the TRADEX L-band radar on Roi-Namur. Two passive remote sites are located on the islands of Gellinam and Illeginni to the east and west sides of Kwajalein Atoll. In the case of the MMS, which was designed over twelve years ago on a limited budget, the benefits of multi-lateration are realized only after the mission has flown. However, the principles of a multi-laterating radar system are well understood, and today's technology would allow such a system to

function at whatever level of real-time operation is needed for the application. A study to define and evaluate such an alternative is needed.

The domain of the MMS is limited to the vicinity of the Kwajalein Atoll since the baselines are relatively short compared to the distances to some points of interest. However, some modest improvements that exploit modern technology could improve the accuracy of the MMS. These include the installation of atomic clocks and recording devices at all three sites, and the use of fiber optics to network the sites together. Such improvements would free MMS from its dependence on the existing surface communication links that suffer from atmospheric delays and multipath effects that limit its absolute calibration accuracy. The two remote sites could be relocated to the islands of Kwajalein and to Ebadon in the atoll in order to increase the baselines and thereby reduce the dilution of precision by a factor of two or more.

Beyond the Kwajalein Atoll, multi-lateration sites could be built on nearby atolls (Likiep and Rongerik, for example). In this case, a wideband radar (such as the GBR-X radar to be built on Kwajalein, or a wideband upgrade to the existing TRADEX S-band radar on Roi Namur) could be the illuminator and provide the necessary sensitivity and resolution. Very long baselines become feasible. However, it also becomes more difficult to communicate with the more distant sites, which would have to function more autonomously and process shared tracking information in place.

For those cases where GPS may not be appropriate for achieving metric accuracy, a multi-laterating radar system is a viable candidate that poses low technological risk. An in-depth study needs to be conducted to examine and provide a detailed design for this alternative. It is expected this study will cost \$150K and take one year to complete.

7.3 INVESTIGATION OF SYSTEMS SUITABLE FOR IMPACT SCORING

Scoring systems have classically included the Hydroacoustic Impact Timing System (HITS), the Splash Detection Radar (SDR) and the Sonobuoy Missile Impact Location System (SMILS). HITS was operational in the Kwajalein lagoon for many years and then put on inactive status by removing the hydrophones and velocimeters. Recently, upon reactivation of the system, it was concluded that the in-water components had deteriorated to such a point that HITS is no longer available and a completely new system is required. Similarly, the SDR's have exceeded their life expectancy with no source of major repair parts. Therefore, no system modifications to the SDR's are recommended. SMILS is applicable only to the Broad Ocean Area, and is expensive to operate.

It is time to consider new options to satisfy the scoring needs at Kwajalein. Therefore we recommend consideration of several alternatives and a small study to determine the most cost-effective option. Among the options that should be considered includes:

- 1) Replace the Splash Detection radars with new radars capable of detecting water plumes as well as providing mid-atoll security or other necessary range support functions.
- 2) Bottom mounted hydrophones with tethered RF link for both lagoon and atoll proximity scoring. This system would be capable of all-weather scoring.
- 3) A SMILS system that uses GPS for sonobuoy location.
- 4) A combination of existing sensors with upgrades and GBR-X to provide scoring. GPS will provide location for vehicles equipped with transponders to impact. Possibly the combination of these minimal augmentation will be capable of providing adequate scoring capability.

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A short study would identify the most cost effective option for satisfying the impact scoring needs. This study will cost approximately \$50K and take 6 months to complete.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Users of the Western Test Range state they are generally satisfied with the metric data they are receiving from the mission reports and expressed their desire to continue having the present data collection capability available in the future. However, there is need for additional signature measurement capability, particularly optical signature measurement capability in the infrared spectral regions. The primary conclusions of this study are summarized as follows.

- A. Future trends in testing at USAKA will include more complicated tests with signature as well as metric data requirements.
 - 1. Multiple object test, with measurements required on up to 20 targets, will be conducted.
 - 2. Optical signatures will be required more frequently as part of the test data products.
- B. USAKA radar sensors will be able to meet future radar user needs with the addition of GBR-X and a few modifications to the existing radars.
 - 1. GBR-X transition to a range sensor is a major activity and will require input from USAKA during design and construction in order to smoothly transition to a range asset.
 - 2. Modifications to existing sensors should be initiated to upgrade systems. A prioritized list has been developed and is included in this report.

C. User needs for optical signature data at USAKA cannot be met with current systems.

1. New optical systems such as OAMP, AST, Upgraded ARGUS and HALO/IRIS can provide some valuable data to assist in defining an optimum USAKA optical measurement capability. However, they are not adequate for all wavelength regions with required sensitivity and accuracy.
2. Other platforms such as high altitude aircraft, probes, balloons, or satellites may be required to ensure required data for discrimination studies are obtained without atmospheric effects. MSX will provide some of this data collection capability.

D. Increased long range metric accuracy will be needed in the future at USAKA.

1. GPS can provide increased metric accuracy for targets equipped with translators.
2. Other systems such as a multi-lateration system may be required for increased metric accuracy for objects without translators.

E. Impact scoring system at USAKA needs to be upgraded.

1. Hydroacoustic Impact Timing System (HITS) has deteriorated beyond repair.
2. Splash Detection Radars (SDR) have exceeded their life expectancy.

3. New systems such as GBR-X and GPS have potential utility and when combined with KREMS and existing systems have some potential for scoring. This will need to be supplemented with a dedicated scoring system but may reduce the load on such a system sufficiently to allow utilization of a less costly system.

The specific capabilities and the time schedule of implementation are described in Figure 1 of Section 2. In order to achieve these new capabilities, the following recommendations need to be implemented.

1. A program for transitioning GBR-X into a range sensor must be aggressively pursued with significant USAKA participation. Range personnel need to be involved in transition planning and implementation at early phases of GBR-X development.
2. USAKA needs to initiate a community wide optics/platform/availability study to determine appropriate USAKA optics capability.
3. Implement the prioritized list of system modifications to upgrade current system capability.
4. Investigate improved long range metric capability as users respond to GPS availability and utility.

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APPENDIX A

USER NEEDS FOR UNITED STATES ARMY KWAJALEIN ATOLL (USAKA) DATA

FOREWORD

This report is prepared in order to document the test measurements required from the USAKA area and its facilities. A special attempt has been made to describe these user needs in terms of the information required to satisfy mission requirements, and not in terms of sensor measurement parameters. This report is submitted in fulfillment of paragraph 2.1 of the Scope of Work and in partial fulfillment of CDRL 004 of Contract #DASG60-89-C-0013 from the U.S. Army Strategic Defense Command.

This report contains data obtained from the Range Users Working Group, Dr. Peter Hirsch of Visidyne, Dr. Jerry Freedman, Mr. Milton Trichel, and Mr. Donald Strietzel of ERIM, and Mr. Glenn Armistead and Mr. Ray Holland of Lincoln Laboratories. Much of the information contained herein was assimilated by the latter five contributors as part of the USAKA Long Range Plan Development Activity.

TABLE OF CONTENTS

A.1.0 Introduction.....	52
A.2.0 Operational Tests..... [MM-II, MM-III, TRIDENT, PEACEKEEPER]	56
A.3.0 New ICBM Delivery System Development Tests..... [MX, Small ICBM, IPMS]	63
A.4.0 New ICBM Reentry Vehicle Development Tests..... [MAST, SENT, TDMaRV, HAVE FURY]	66
A.5.0 ICBM Penails Development Tests with Proven Delivery Systems. [FTM-17, ERPA, PYRO, BRV Penaid]	72
A.6.0 SDIO Validation Tests and Data Base Development..... [HEDI, ERIS, EDX, GBR-X, AOA, GSTS]	78
A.7.0 Intelligence Mission Requirements.....	109
A.8.0 Space Surveillance Mission Requirements..... (NFLS, DEEP SPACE, SOI)	115
A.9.0 Physical Phenomena and Scientific Measurements.....	122
A.10.0 Summary.....	130

A.1.0
INTRODUCTION

The primary users of data collected at United States Army Kwajalein Atoll (USAKA) are the DoD organizations responsible for the development and maintenance of the US offensive and defensive ballistic missile capability. Additional missile data users are the intelligence community and organizations with space satellite and object surveillance and monitoring responsibilities such as Space Command and NASA. The final category of USAKA data user includes non-missile and space object data users such as those interested in physical and atmospheric phenomena measurements (for example; the Defense Nuclear Agency and NASA).

USAKA is the terminus of an array of US facilities beginning on the West coast, including facilities on the various Hawaiian Islands and potentially on smaller islands such as Wake, Midway and Johnston Islands and also potentially in orbit. This array of facilities is used for three main data collection purposes:

- Developmental testing of advanced offensive ballistic missile systems and components,
- Confidence assessment of existing operational ballistic missile systems, and,
- Research on and developmental testing of ABM systems and their components.

Additionally, USAKA facilities are used to study orbital objects. The principal roles of USAKA's data collection requirements appear to be as follows:

- The most fundamental role is to provide a sort of "ground truth" which can be used to determine what actually happened in a test. The data to be provided can, however, span a very broad range of complexity, ranging from, e.g., trajectory and impact determination to, e.g., the validation of performance of decoys. It can be anticipated that requirements will commonly originate from a single user, especially SDIO, but, if offensive technology advances, spread to other users.
- A second major role is to provide a surrogate, i.e., surrogate for either the "real" (or prototype) sensor or for the real target, information in the testing of ABM system components and concepts. Again, this can range from providing relatively simple tracking data to performing complex discrimination tasks which would ordinarily be provided or performed within the ABM system itself.
- A third major role is to acquire data supporting the development of ABM system components (or their defining requirements). As an example, the GBR-X is certainly not identical to any of the KREMS radars, but much of the data and experience needed for its specification was obtained with the KREMS radars.
- The final missile range sensor function is a supporting function namely to monitor (and support prediction of) the missile range meteorological environment and to monitor safety.
- The USAKA sensors have the additional function of studying orbital objects and Soviet ballistic missiles fired into the area.

In this report, the users of data from USAKA are discussed in terms of data needs at the level of information required. The intent is to define the mission and measurement objectives of the various users of data, independent of range instrumentation.

Potential changes in the users of the USAKA facilities include an expanded intelligence role for monitoring foreign launches and space surveillance, an expanded role as a test bed for simulating foreign sensors, and as a testing facility for ASAT, DEW or Cruise missiles. An additional role which may become more important in the future is as a special target imaging and signature measurement facility.

The specific user needs which will be discussed in this report include the user categories listed in Table A.1.

Table A.1
USER CATEGORIES

USAKA DATA GATHERING OBJECTIVES FOR FOUR TYPES OF CONVENTIONAL ICBM MISSIONS:

- Operational Tests
- New Delivery Systems
- New RV Development
- Penaids Development

USAKA DATA GATHERING OBJECTIVES FOR OTHER TYPES OF MISSIONS:

- SDIO (Validation Tests and Data Base Development)
- Intelligence (Pony Express)
- Space Surveillance Mission
- Physical Phenomena and Atmospheric Measurement Missions

A.2.0

OPERATIONAL TESTS

[MM-II, MM-III, TRIDENT, PEACEKEEPER]

The largest user of USAKA for the past twenty years has been Strategic Air Command (SAC) utilizing the measurement capability of the sensors on USAKA to routinely test the operational readiness of the land based US ballistic missile forces. In these tests, the primary objective is to measure the flight characteristics to validate the operational specifications of ballistic missile systems. The specific information required in order to meet this objective is included in Table A.2.

Both exoatmospheric data during midcourse and endoatmospheric data during reentry are required. Sections A.2.1 through A.2.3 describe the information needed from the late midcourse phase of flight and sections A.2.4 through A.2.7 describe the information needed from the reentry phase.

The ability of a proven booster delivery system to properly deploy proven payloads is primarily evaluated from the performance of the payload in reentry. Both metric and signature data for diagnosis of the payload during reentry and, if applicable, its emergence from chaff, are needed.

A.2.1 PROPER DEPLOYMENT OF PAYLOADS

In order to ensure the proper deployment of payloads, it is necessary to be able to detect, identify, and track the objects in the complex. The number of objects in the complex typically is three but varies from one to ten. In the future, this number is expected to increase with ten becoming a more common number of objects to be tracked in a target complex.

Objects are identified either by beacons from the object or their location and signature. Objects need to be located to within ± 50

Table A.2.
ICBM OPERATIONAL TEST
(Proven payloads and Delivery System)

Objective: Measurement of flight characteristics to validate operational specs.

A. EXOATMOSPHERIC

1. Proper Deployment of Payloads
 - Object acquisition and count
 - Object identification
 - Trajectory (coarse) + PBV
 - Payload angular dynamics
 - Pierce point accuracy (fine trajectory)
2. Proper Deployment of Chaff
 - Cloud count and pattern
 - Placement of targets in clouds
3. Confirm Signature Specs (RF, Optics)
 - Payload
 - Chaff

B. ENDOATMOSPHERIC

4. Metric Accuracy (Fine Trajectory)
 - Reentry dispersions
 - Ballistic coefficient
 - Impact point (location and time)
5. Confirm Signature Specs (RF, Optics)
 - Body emergence from Chaff
 - Body
 - Wake
6. Diagnostics
 - RV integrity
 - Roll resonance
 - Angle-of-attack convergence
7. Arming and Fusing

meters in range and ± 0.5 milliradians in angle. Tracks are needed on objects at several points in trajectories in order to validate trajectories of objects from acquisition to splash down.

The payload angular dynamics (coning angle, spin rate, and precession rate) must also be determined. In order to determine these parameters the data collection span for typical precession periods is approximately 30 to 60 seconds.

Pierce point is needed in order to separate the guidance error to pierce point from the reentry error to impact. SAC and Peacekeeper requires pierce points to 30 m accuracy with respect to Geodetic System Coordinates.

A.2.2 PROPER DEPLOYMENT OF CHAFF

SAC MM-III requires the determination of chaff cloud location in space to within 500 meters within the altitude interval of 400-120 kilometers. SAC MM-II requires cloud position accuracy (relative to other clouds) of 900 m from acquisition to loss-of-attack.

Metric tracks of targets masked by the chaff clouds at some frequencies are necessary in order to determine relative placement of the targets in the chaff clouds.

A.2.3 CONFIRM SIGNATURE SPECS (RF, OPTICS)

Measurements of the operational ICBM's are necessary for diagnostics and to validate viable payload conditions. The Navy requires full collection of signature data at all frequencies. Signature data requirements for SAC MM-III are very limited except for chaff missions. For SAC MM-II signature data at C-band and UHF are required for body motion determination and from VHF through C-band for chaff missions. The Navy requires Ka-Band, C-Band, S-Band, L-Band, UHF, VHF, W-Band, UV, Visible, SWIR, MWIR and LWIR.

SAC requires signature data at S-Band, L-Band, UHF and VHF for chaff missions. Measurements are used to characterize the extent, growth rate and overall RCS density of the clouds.

A.2.4 METRIC ACCURACY (Fine Trajectory)

Metric measurements are required to determine errors or flight deviations during reentry from a planned trajectory. Contributors to these dispersions include mass loss, angle-of-attack variations affecting drag and lift forces and environment (winds and density). SAC and SAC Peacekeeper accuracy statements are for 20 m accuracy. For typical Peacekeeper trains of multiple objects, coverage on all payloads is required. Navy requirements are for 6 m accuracy in position and .3m/s velocity. On-board sensors (i.e., accelerometers), when available, are used to measure drag/lift forces and angle-of-attack variations.

Reentry dispersions may be caused by conditions related to the environment. Winds and density data are needed at various altitudes near the time of mission events. Peacekeeper (SAC) requires pressure, temperature and relative humidity measurement accuracies of (.4% to 1.6%), (1°C to 2.5°C) and (5% to 20%), respectively. Variations in accuracy requirements are altitude dependent and would be stated in the Program Requirements Document. See Range Commanders Council document 353-87, "Meteorological Data Error Estimates." Refraction effects within the troposphere cause errors in the measurements of elevation and range. These errors vary due to a gradual increase in the refractive index with decreasing altitude. Models updated by measurements to isolate these errors are required. See document 353-87.

The deceleration experienced by a reentry vehicle is directly proportional to its ballistic coefficient. The ballistic coefficient ($W/C_D A$) is expressed by the ratio of vehicle weight (W) to drag coefficient (C_D) and a fixed base area (A). The drag deceleration is a measurable parameter related to dynamic pressure as well as W and

$C_D A$. The ballistic coefficient may be derived if the atmospheric density profile, velocity and drag deceleration history are known. Measurements are made to derive deceleration from on-board sensors. Atmospheric density profile is mandatory for the determination of the ballistic coefficient. See Peacekeeper PRD for measurements and accuracy requirements. Also, see document 353-87.

Impact point, commonly referred to as impact scoring, is required to determine target-miss distance in down-range and cross-range relative to the flight trajectory plane. SAC and SAC Peacekeeper requirements are 20 m accuracy. Peacekeeper requires RV-to-RV Impact Location of 10 m with respect to other RVs. Note that the stated Peacekeeper requirement is primarily for USAKA-N impact location. Navy requires 7.5 m in position. Time of impact is also required for all users.

A.2.5 CONFIRM SIGNATURE SPECS (RF, OPTICS)

These measurements are for diagnostic purposes and provide confirmation of expected performance. Sufficient data are required for evaluating non-nominal behavior of the target complex. Accuracy requirements exist in the metric areas but no RCS accuracies are known to exist outside of standard sensor calibration capabilities.

Altitude of both body emergence and chaff pancake events are required for monitoring body emergence from chaff. SAC MM-II requires an altitude accuracy for this measurement objective of 1500 m at emergence.

Body signatures are required by the Navy and SAC MM-II which are also normally required for SAC MM-III. KA-Band, C-Band, S-Band, L-Band, UHF, VHF bands including both NB and WB, where applicable, are required for signatures by the Navy. W-Band measurements are desired by the Navy. These data are normally required for SAC usage for diagnostic purposes. There are no stated accuracy requirements for KA-Band. SAC MM-III accuracy of ± 1 dBsm is applicable only for data to be evaluated post-mission, while the Navy has no stated accuracies.

SWIR/MWIR/LWIR are mandatory or required data requirements for the Navy and UV/Visible data for the Navy is desired.

W-Band wake measurements are desired by Navy. K_A-Band/C-Band/S-Band/L-Band/UHF/VHF including both NB and WB, where applicable, are required for wake signature by the Navy and are desired by SAC for diagnostic purposes. There are no stated accuracy requirements by any user for wake data.

A.2.6 DIAGNOSTICS

RV integrity measurements are made to verify that the RV flight characteristics are performing as expected. Flight variations are detected through metric and signature measurements. Unusual body motion is monitored by on-board sensors and is an important diagnostic measurement.

Characterization of water (ice) in the context of (Weather Severity Index) WSI is required to determine any potential impact on RV performance over the reentry path. The determination of the WSI over reentry path as close as possible to the time of payload passage is required.

The dynamic spin motion experienced during reentry becomes more complex as the aerodynamic forces modify the exoatmospheric coning motion. As the coning or pitching frequencies increase and match the roll rate, a condition of roll resonance occurs. An increasing roll rate and a decreasing pitching frequency also creates a roll resonance (or lock-in) condition. Depending on the altitude of occurrence, dispersions of large magnitude may be observed. Analysts utilize rate sensor data for vehicle motion analysis.

The angle of attack history is also required for evaluating vehicle performance. Analysts utilize rate sensor data for vehicle motion analysis, in determining the angle of attack history.

A.2.7 ARMING AND FUSING

The requirement here is to measure the time and altitude of the event. SAC's reentry accuracy requirement for all ICBM systems is 20 m. On-board sensors provide the occurrence and time of the event.

A.3.0

NEW ICBM DELIVERY SYSTEM DEVELOPMENT TESTS

[MX, SMALL ICBM, IPMS]

The development of new ICBM delivery systems is part of the continual evolution of more accurate and capable ballistic missile weapons systems. The objective of the tests is generally to confirm that these new systems and components operate as designed and conform to system specifications. Table A.3 summarizes the required information needed to accomplish the test objectives at USAKA for new delivery system validation. Sections A.3.1 and A.3.2 describe the information needed from midcourse and sections A.3.3 through A.3.6 describe the data needed from reentry.

A.3.1 PROPER DEPLOYMENT OF PAYLOADS

The information needed to ensure proper deployment of payloads is the same as that needed for operational tests as described in Section 2.1.

A.3.2 CONFIRM SIGNATURE SPECS (RF, OPTICS)

For this case (new delivery system with proven payloads), these measurements are of a diagnostic nature to validate viable payload conditions and to evaluate delivery system performance. Actual data required may vary from mission-to-mission. However data from all available existing sensors for diagnostic signatures are considered mandatory or required by BSD. Coverage on multiple objects, including closely spaced objects is required.

W-Band and X-Band signatures are desired by BSD. BSD indicates mandatory or required measurement requirements for data in visible, SWIR, MWIR, and LWIR from a platform at least 40,000 feet altitude.

Table A.3.
NEW ICBM DEVELOPMENTAL TEST-NEW DELIVERY SYSTEM

OBJECTIVE: Measurement of Payload Flight Characteristics to Validate System Specs.

A. EXOATMOSPHERIC MEASUREMENTS

1. PROPER DEPLOYMENT OF PAYLOADS
 - Objective Acquisition and Count
 - Object Identification
 - Trajectory (Coarse) + PBV
 - Payload Angular Dynamics
 - Pierce Point Accuracy (Fine Trajectory)
2. CONFIRM SIGNATURE SPECS (RF, OPTICS)

B. ENDOATMOSPHERIC MEASUREMENTS

3. METRIC ACCURACY (FINE TRAJECTORY)
 - Reentry Dispersions
 - Ballistic Coefficient
 - Impact Point (Location and Time)
4. CONFIRM SIGNATURE SPECS (RF, OPTICS)
 - Body
 - Wake
5. DIAGNOSTICS
 - RV Integrity
 - Roll Resonance
 - Angle-of-attack Convergence
6. ARMING AND FUSING

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The explicit requirements of BSD are contained in the detailed user requirements data base. UV measurements are desired by BSD.

A.3.3 METRIC ACCURACY

Metric measurement requirements are the same as were stated in paragraph 2.4 for the Operational Tests (MM-II, MM-III, Trident, and Peacekeeper).

Determination of impact point, location and time, commonly referred to as impact scoring, is required to determine target-miss distance in down-range and cross-range relative to the flight trajectory plane. SAC, Peacekeeper and small ICBM requirement are 20m accuracy. Peacekeeper requires RV-to-RV Impact Location of 10m with respect to other RVs. Note that the stated Peacekeeper requirements is primarily for USAKA-N impact location.

A.3.4 CONFIRM SIGNATURE SPECS (RF, OPTICS)

Signatures for diagnostics during reentry are desired. No other specifications for proven payloads. Signature measurements are similar in requirements as stated in paragraph 2.5 above.

A.3.5 DIAGNOSTICS

Diagnostic measurements are similar in requirements as previously described under paragraph 2.6.

A.3.6 ARMING AND FUSING

The requirement here is to measure the time and altitude of the event. User's requirement is 20m for altitude.

A.4.0

NEW ICBM REENTRY VEHICLE DEVELOPMENT TESTS
[MAST, SENT, TDMaRV, HAVE FURY]

The development of new ICBM reentry vehicles must include the collection of data from actual launches and reentries to establish a data base for the RV signatures, metrics, and flight dynamics. The collected data must provide adequate information and resolution to detect any anomalous events and support their analyses. Table A.4 lists the required data to accomplish the mission objectives for new RV technology development.

Both exoatmospheric data during midcourse and endoatmospheric data during reentry are required. Section A.4.1 through A.4.3 describe the information needed from the late midcourse phase of flight and section A.4.4 through A.4.6 describes the information needed from reentry.

A.4.1 PROPER DEPLOYMENT OF PAYLOADS

The objective of this measurement is to detect and track up to ten objects in the complex for overall count. It is desirable to have autonomous search and acquisition for tracking multiple objects simultaneously. The objects must be identified and located in real-time to within ± 50 meters in range and ± 0.5 mrad in angle. Some or all of the reentry vehicles will have on-board sensors and have the capability to transmit an identification signal.

The trajectory of the objects must be measured accurately. Accuracy for this measurement varies but must be sufficient for sensor-to-sensor handover and acquisition. Also implied is sensitivity for long-range execution of this function and a good program to smooth and extrapolate 30 to 60 seconds of track. The collection of on-board multiple trajectory sensor data is required.

The measurement of payload angular dynamics is required and should include coning angle, spin rate and precession rate. The collection

Table A.4.
NEW ICBM REENTRY VEHICLE DEVELOPMENT TEST

Objective: Measure payload flight characteristics to determine payload performance.

A. EXOATMOSPHERIC

1. Proper Deployment of Payloads
 - Object acquisition and count
 - Object identification
 - Trajectory (coarse)
 - Payload angular dynamics
2. Determine Signatures (RF, Optics)
3. Determine Reentry Conditions
 - Fine motion
 - Pierce point

B. ENDOATMOSPHERIC

4. Metric Accuracy
 - Reentry dispersions
 - Ballistic coefficient
 - Impact (location and time)
5. Determine Signature (RF, Optics)
 - Body
 - Wake
 - Angle of attack history
 - RV integrity
6. Arming and Fusing

of on-board sensor data such as accelerometers or rate-gyros further augment the determination of angular dynamics.

A.4.2 REENTRY VEHICLE SIGNATURES

For this case, where the RVs are often in the pre-prototype stage, there is no data base of exo signatures. In some instances, few if any static range measurements have been made. Accordingly, there is a requirement to collect signature data under plausible deployment conditions. Coverage on multiple objects, including closely spaced objects, must provide adequate signature data to determine and analyze anomalous RV flight dynamic behavior.

A.4.3 REENTRY CONDITIONS

In order to evaluate signature and metric reentry data, a set of initial conditions must be determined. This starting point is usually taken to be 120 km altitude, before the sensible atmosphere causes slow down or changes to body angular motion.

Fine motion of the RVs must be determined. This refers to the nearly imperceptible wobble in a vehicle's motion introduced by slight mass imbalances. The determination of pierce point is important in order to separate the guidance error to pierce point from the reentry error to impact. No accuracy requirements are stated in official documentation, but it is customary to process data from these missions to the limit in order to achieve the best possible pierce point and subsequent trajectory determination.

Telemetry from on-board sensors (if available) must be recorded to augment other remote sensor measurements.

A.4.4 METRIC ACCURACY

The measurement of reentry dispersion of the RVs is required to determine errors or flight deviations during reentry from a planned

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trajectory. Contributors to these dispersions include mass loss, angle-of-attack variations affecting drag and lift forces and environment (winds and density). No accuracies are stated, but best possible are needed so that the reentry trajectory can be analyzed for anomalies.

The acquisition of data transmitted from on-board sensors (accelerometers) is required to measure drag/lift forces and angle-of-attack.

Weather conditions, and especially atmospheric water content and particle size, at or very near the reentry point is required at the time of reentry. The measurement will provide the determination of the Weather Severity Index (WSI) and potential impact on RV performance over the reentry path. Reentry dispersion may be caused by conditions related to the environment. Data of wind velocity and density should be measured near the time of mission events. No accuracy requirements are stated.

Refraction effects within the troposphere cause errors in the measurements of elevation and range. These errors vary due to a gradual increase in the refractive index with decreasing altitude. Actual measurements are needed to update models to correct for these errors.

Deceleration and the requirement to determine the Ballistic Coefficient is the same as described previously under paragraph 2.4.

Accurate impact point location and timing is required for new reentry vehicles to determine target-miss distance in down-range and cross-range relative to the flight trajectory plane. Accuracy of 10 meters is required for lagoon impacts.

The time of impact is determined by the time of the loss of the telemetry signal received from the RV.

A.4.5 REENTRY SIGNATURES

Reentry signatures are part of the profile that is required in the accumulation of a data base of new reentry vehicles. The data

collected is for diagnostic purposes or used as a data base upon which decoys are designed. Full spectrum optics in addition to RF has been noted to be of increasing interest and desirability.

The reentry vehicle body generates unique signature characteristics during reentry. Sheathing altitude, sheathing effects and boundary layer transition are examples of body observations made during reentry. Body signatures must be separable from the wake signature. Data must be collected for analysis of wake characteristics such as wake onset altitude, length, and wake velocity profile.

The angle of attack history and trajectory needs to be determined for evaluating vehicle flight performance. The acquisition of on-board rate sensors data for vehicle motion must be recorded to augment this measurements taken from remote sensors.

The integrity of the reentry vehicle must be verified by the measurement of the RV flight characteristics. Metric and signature measurements are required to determine variations from expected performance with respect to actual RV performance. The acquisition of data from on-board sensors is required for diagnostic purposes.

Metric data is used to construct a reference trajectory for studies on both reentry events or deviation and for diagnosis of trajectory variations. Altitude variation from a reference trajectory is important for correlating anomalous events. No stated accuracy requirement exists for this metric measurement.

Measurement of weather conditions and correction of refractive error effects as described previously in paragraph 2.4 are also required for the measure of RV integrity.

A.4.6 ARMING AND FUSING

The requirement here is to measure the time and altitude of the arming and fusing event. The acquisition of on-board sensor data provides the occurrence and time of the arming and fusing event. Other metric measurements contribute to the generation of an altitude

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measurement of the event occurrence. No accuracy requirements are known to exist.

A.5.0

ICBM PENAIDS DEVELOPMENT TEST WITH PROVEN DELIVERY SYSTEMS
[FTM-17, ERPA, PYRO, BRV PENAID]

Decoys to be tested on ICBMs are often in early stages of development. Frequently they are carried down-range on a Minuteman I missile and dispensed by devices not designed to replicate operational deployment. Hence, the relevance of some metric measurements such as object pattern and pierce point will not be the same for all missions of this category. Relevancy of these measurements depends upon the degree to which PENAID development test deployment approximates the actual operational deployments.

At least three different types of decoys are tested at USAKA: 1) lightweight, full size balloon (exoatmospheric only); 2) heavier full size decoys having the same shape as the RVs which they simulate (survive reentry); and 3) deep endoatmospheric decoys which are a small fraction of actual RV size and are usually built to resemble an RV radar cross section over a single frequency and match the velocity until demise at about 15 to 20 kilometer altitude.

For all these decoy categories, the same type of measurements (exo and endoatmospheric) that are taken on real RVs must also be taken on the decoys. The development of PENAIDS must include the collection of data from actual reentries to establish a data base for the decoy signatures, metrics, and flight dynamics. The collected data must provide adequate information and resolution to detect any anomalous events and their subsequent analyses. Table A.5 lists the required measurements to accomplish the mission objectives for PENAID technology development.

Both exoatmospheric data during midcourse and endoatmospheric data during reentry are required. Sections A.5.1 through A.5.3 describe the information needed from the late midcourse phase of flight and Sections A.5.4 through A.5.7 describes the information needed from reentry. The main differences between decoy and RV missions are

Table A.5
ICBM PENAIDS DEVELOPMENTAL TEST
(Proven Delivery System)

Objective: Measure penaids (i.e., decoys) characteristics for experimental evaluation.

A. EXOATMOSPHERIC

1. Proper Deployment of Decoys
 - Object acquisitions and count
 - Object ID
 - Coarse trajectory (for handover)
 - Decoy angular dynamics
 - Relative placement of decoys
2. Determine Signature (RF, Optics)
3. Determine Reentry Conditions
 - Fine motion
 - Pierce point

B. ENDOATMOSPHERIC

4. Trajectory
5. Ballistic Coefficient
6. Determine Signature (RF, Optics)
 - Body
 - Wake
 - Angle of attack history
7. Survival

that decoy missions usually have more payloads which require full data collection than does an RV mission.

A.5.1 PROPER DEPLOYMENT OF PAYLOADS

The objective is to detect and track all objects in the complex for overall count. It is desirable to have autonomous search and acquisition for tracking multiple objects simultaneously. The objects must be identified and located in real-time to within ± 50 meters in range and ± 0.5 mrad in angle. Some or all of the decoy vehicles will have on-board sensors and have the capability to transmit an identification signal.

The trajectory of the objects must be accurately measured. Accuracy for this measurement varies but must be sufficient for sensor-to-sensor handover and acquisition. Also implied is sensitivity for long-range execution of this function and a good program to smooth and extrapolate 30 to 60 seconds of track. The collection of on-board multiple trajectory sensor data is required.

The measurement of decoy angular dynamics is required and should include coning angle, spin rate and precession rate. The collection of on-board sensor data such as accelerometers or rate-gyros further augment the determination of angular dynamics.

When deployment of decoys occurs from an operational style device, the resulting pattern of decoys and support modules is an important measurement. Metric measurements are required to perform analysis on the pattern of objects in the complex relative to each other. The measurements should be capable of determining and/or evaluating the performance of the deployment mechanism by examining relative object placement rather than absolute trajectory placement. Analysis of trajectory measurements should yield a relative placement accuracy on the order of 10 meters (object-to-object).

A.5.2 PENAID (DECOY) SIGNATURES

For this case, where the decoys are in the development stage, there is no data base of exoatmospheric signatures. In some instances, few if any static range measurements have been made. The requirement then is to collect signature data under plausible deployment conditions. Coverage on multiple objects, including closely spaced objects, must provide adequate signature data to determine and analyze anomalous conditions.

A.5.3 REENTRY CONDITIONS

In order to evaluate signature and metric reentry data, a set of initial conditions must be determined. This starting point is usually taken to be 120 km altitude, before the sensible atmosphere causes slow down or changes to body angular motion.

Fine motion of the decoy must be determined. This refers to the nearly imperceptible wobble in a vehicle's motion introduced by slight mass imbalances. If the decoy is operationally deployed, then the determination of pierce point is important in order to assess the deployment mechanism and planned reentry pattern. For the non-operationally deployed (the majority of decoys) pierce point is important for the reentry to demise trajectory determination. No accuracy requirements are stated in official documentation, but it is customary to process data from these missions to the limit in order to achieve the best possible pierce point and subsequent trajectory determination.

Telemetry from on-board sensors (if available) must be recorded to augment other remote sensor measurements.

A.5.4 TRAJECTORY

The measurement of decoy trajectories is required to determine the effectiveness of decoys to simulate real RVs. A high quality

trajectory from pierce point to demise is needed on each decoy in order to assess its credibility and to serve as a reference for other observables. No accuracies are stated, but best possible are needed so that the reentry trajectories can be analyzed for credibility. The acquisition of data transmitted from on-board sensors (if available) is required to measure drag/lift forces and angle-of-attack.

Data of wind velocity and density should be measured near the time of mission events. No accuracy requirements are stated. Refraction effects within the troposphere cause errors in the measurements of elevation and range. These errors vary due to a gradual increase in the refractive index with decreasing altitude. Models updated by measurements to isolate these errors are required.

A.5.5 BALLISTIC COEFFICIENT

In order to match the deceleration of larger RVs, the deceleration experienced by a decoy must be determined. The ballistic coefficient must be determined as described previously for real RVs. The ballistic coefficient can be derived if the atmospheric density profile, velocity and drag deceleration history are known. Decoy metric data must be collected to determine the ballistic coefficient. Other measurements from on-board sensors must also be recorded during reentry to augment the metric data.

Measurement of weather conditions and correction of refractive error effects as described above are also required for the ballistic coefficient determination.

The time of demise is determined by the time of the loss of the telemetry signal received from the decoy (if available).

A.5.6 PENAID REENTRY SIGNATURES

Reentry signatures are part of the profile that is required in the accumulation of a data base of decoy development. The data is collected for diagnostic purposes and also used as a data base upon

which decoy designs are improved to better simulate actual RVs. Full spectrum optics in addition to RF is becoming of interest from pierce point to 50,000 feet altitude.

The decoy body generates unique signature characteristics during reentry. Sheathing altitude, sheathing effects and boundary layer transition are examples of body observations made during reentry. Body signatures should be separated from the wake signature. Data must be collected for analysis of wake characteristics such as wake onset altitude, length, and wake velocity profile. The small decoy bodies must produce a wake reasonably like the much larger RVs. These important measurements serve to determine whether the decoys are a credible match to the RV's for which they are designed simulate. No accuracy requirements have been stated.

The angle of attack history and trajectories must be determined for evaluating decoy performance and for interpreting other observations. The acquisition of on-board rate sensor data for vehicle motion must be recorded to augment this measurement.

A.5.7 SURVIVAL

The decoy must survive to a specified altitude. Observations of demise and its conditions (immediate and catastrophic or slow and partial) must be made by direct signature and indirect fine trajectory measurements. Metric and signature measurements are required to determine variations from expected performance with respect to real RVs. The acquisition of data from on-board sensors must be made to determine conditions preceding demise and the time of demise. There are no stated accuracy for these measurements.

A.6.0

SDIO VALIDATION TESTS AND DATA BASE DEVELOPMENT
[HEDI, ERIS, EDX, GBR-X, AOA, GSTS]

The desire to develop a defensive capability to protect either selected sites or CONUS from ballistic missile attack has long been a national priority. The Nike Zeus program in the 1960's and Spartan and Sprint programs of the 1970's and SDI program in the 1980's, have resulted in a continually evolving demand for data and data collection facilities at USAKA. The origins of many of the sensors at USAKA have been to develop and evaluate detection, discrimination, and tracking techniques in support of the investigation of strategic defensive systems.

In the next five years, there are several test programs scheduled to be conducted at USAKA for SDI. These programs are included in Table A.6. These programs are significantly different than those discussed previously in that they generally involve testing which includes its own sensor. Thus the objective is often to evaluate a specific sensor concept rather than specific target characteristics. For these cases, the demand on USAKA sensors is frequently to provide ground truth. In addition, in the case of tests that involve intercepts, it will include evaluation of miss distance or kill effectiveness.

USAKA is located so that it cannot see the boost phase of missiles launched from the US West Coast. Therefore, it is concerned only with the midcourse and terminal phases of a ballistic missile trajectory. During these phases, discrimination, rather than detection or tracking, is ordinarily the source of the most critical sensor requirements. The US is conducting research on three basic types of discrimination sensors. These are passive sensors (usually thermal IR), active sensors (usually radar or laser radar), and interactive

discrimination in which an object is perturbed by some external agent (e.g., a laser beam) and its response to this perturbation is observed.

Much discrimination methodology is based on the fact that throw weight is much more expensive than the corresponding warheads. Therefore, an opponent is unlikely to utilize heavy decoys, as the weight would be better used in carrying additional warheads rather than decoys. Most approaches to discrimination are either directly (e.g., atmospheric deceleration) or indirectly (e.g., thermal) sensitive to object mass. While atmospheric deceleration provides the (probably) most robust discrimination capability of all possible approaches, it occurs so late in the trajectory that the battle space is very limited and the implied interceptor requirements are extremely severe to defend even point targets. Thus there is a strong motivation to accomplish discrimination much earlier in the trajectory.

The number of objects to be detected, tracked and discriminated is potentially very high. Current US missiles carry up to 10 warheads, which are typically accompanied by numerous other objects that serve as penetration aids. At the reentry interface, these can occupy a volume from several kilometers in radius (across trajectory) and hundreds of kilometers in length (along trajectory). These other objects may present discrimination problems ranging from the trivial to the profound.

Passive Sensors

The requirement for day-night operation and a few simple calculations lead to the realization that ordinary (non-coherent) passive sensors must operate in the thermal IR and that the objects will be highly under-resolved. At least when in eclipse, the equilibrium temperature of space objects is below room temperature, implying a need for LWIR wave lengths (except during re-entry). It is also clear that the sensitivities required to detect (and, especially,

to characterize) these objects at long ranges stress the state of the art and that they cannot be accomplished from sea level in the tropics. Necessary sensitivities can be obtained in the LWIR from high altitude air craft in atmospheric window bands, but not in atmospheric absorption bands. The full range of wavelengths, the lowest backgrounds and the full breadth of physics can only be attained by exoatmospheric sensors, although balloon-borne sensors provide an occasionally tempting alternative. It is common for subvisible cirrus, which plays havoc with LWIR observations, to occur at surprisingly high altitudes (55,000 ft.) near USAKA. Thus, even high altitude aircraft platforms are not immune to disruption of IR observations by weather. Exoatmospheric optical observations can be obtained by satellite sensors, "pop up" (sounding rocket borne) sensors, or "fly-along" sensors flown in the ballistic missile itself. In the reentry phase, the objects are rapidly heated and progressively shorter wavelengths (including the visible) become useful. Two useful classes of measurement can be distinguished: metric measurements allowing trajectory determination (including deceleration), and radiometric measurements allowing determination of object thermal dynamics and modulation by e.g., tumbling. Key issues involved in these measurements include frequency of observation (of an object), wavelengths, sensitivity, number of object tracked, field of view and field of regard.

Active Sensors

Active sensors basically consist of micro/millimeter wave radars and laser radars. These are used in two modes, imaging and metric. The imaging mode, which is based on ISAR principles, allows determination of object structure and free-body and reentry dynamics, while the metric mode again allows determination of reentry deceleration. The desires for high resolution imaging, high metric accuracy, and resistance to nuclear induced ionization tend to drive one to shorter wavelengths, while the desire for only range and the

capability to track multiple objects with a single beam tend to drive one to longer wavelengths where high power transmitters are feasible and the beams are fatter. There is a broad range of wavelengths from about 3 mm to 20 microns where the atmosphere is not usefully transparent, so that ground based systems have avoided this range. Future space based systems might preferably operate in these absorption bands, due to the resistance to ground based jamming thereby incurred, but since the object signatures can be adequately understood from window band observations, there is little incentive for the missile range radars to operate in absorption bands. Conventional single beam radars must inherently follow a single target; the axis of the beam is maintained on that target and the three dimensional location of the target is determined by the beam pointing angles and the range to the target. So-called monopulse radars are also able to determine the location of other objects which fall within the beam by determining their angular displacement from the beam axis and their range, but no information is provided on objects outside the beam and there are usually limits on the number of windows in range within which data can be recorded. Phased array radars can rapidly switch between multiple beams, allowing the effectively simultaneous tracking and imaging of larger numbers of objects, but, there are, of course, limitations on the number of multiple beams which can be used simultaneously, as transmitter power is effectively shared among them.

Evaluation of such systems places a number of new and special requirements on USAKA instrumentation.

The first of these is the requirement for highly accurate tracking of multiple objects on quite different trajectories. This requirement arises due to the need to characterize the vector miss distance in tests of interceptions, which, in turn, affects the interceptor maneuvering, impactor and/or warhead requirements. The exact requirement is somewhat unclear, but certainly, it is to be able to characterize misses of no more than a few meters. The required accuracy severely stresses conventional radar, because, if two radars

are used, (one for target, one for interceptor) extraordinarily small biases in their metric accuracy are required, and, if a single radar is used, tracking only one of the vehicles, the second flashes through the beam so rapidly that reliable determination of the second trajectory is problematical.

There are several approaches to doing this. The first is to place the required instrumentation on the interceptor and/or target vehicles and to telemeter the required data back to USAKA. This approach places USAKA requirements only on telemetry but may place unacceptable requirements on the experiment vehicles or other parameters. The second approach is to use a phased array radar, which can track both objects (almost) simultaneously. This approach may make it possible to suppress interbeam biases to an adequate degree and would place particular requirements on the GBR-X. The third approach is to use trilateration, in which both of the objects are illuminated (or beacons aboard them interrogated) by a single ground based radar and the return signals are received by a network of three (or more) receivers, allowing a highly accurate determination of the position of each vehicle, as no angle measurements are required. There is an existing trilateration network at USAKA, but the baselines are too short to provide the needed accuracies at the ranges required. Correction of this deficiency would require placing additional receivers and antennas on other atolls. It may also be possible to provide this capability by triangulation, in which multiple optical sensors would be used to track each vehicle. This would probably also require optical sites on other atolls and would be sensitive to weather. Finally, each vehicle could receive, and telemeter to the ground, signals from the GPS satellites, allowing determination of the relative positions of the two vehicles to an accuracy of about 1-2 meters. The principle drawback of this method is the incomplete temporal coverage provided by the current GPS constellation. This difficulty could be alleviated by installing ground based GPS surrogates on (several) atolls.

Additional major requirements fall in the area of range safety. These are of two categories. First, the high performance (axial acceleration and velocity, maneuverability) of interceptors creates severe range safety requirements. It is not trivial to determine when such vehicles are out of control and, because of their high performance they can pass from safe to dangerous trajectories very quickly.

The most attractive approaches to this problem seem to include combinations of radars or GPS with telemetered data from the on-board guidance, navigation, and control data. These approaches place stringent requirements on radars and tracking antenna slew rates (especially early in the trajectory) and on the rate of trajectory determination.

The second class of range safety issues is the determination that the impact zone of an interceptor, target, or fragments thereof is clear of (innocent) bystanders. While this is basically a simple problem, it is complicated by the size and multiplicity of possible impact zones from such an intercept, by their remoteness from USAKA itself, and by the likely small size of such bystander craft. In many cases, these zones are out of range for any ground based radar.

A final case of issues for KE intercepts lies in telemetry. Such experiments are likely to require substantially more telemetry capability than currently exists at USAKA, simply because of the number of vehicles in such a test, redundancy requirements, and the bandwidth of data to be returned.

Directed Energy Weapons (DEW) or interactive discrimination might also be evaluated along the US West Coast to USAKA corridor, thus implying requirements on USAKA (although we are unaware of any plans to do so). Given our present state of knowledge, it is very difficult to forecast these requirements.

Table A.6
SDIO VALIDATION TESTS AND DATA BASE DEVELOPMENT

Objective: Demonstrate the capability of Defensive System Concepts and provide data for operational system development.

A. EXOATMOSPHERIC

1. Discriminate targets in cluttered environment.
 - GBR-X
 - GSTS
 - EDX
2. Track Targets
 - AOA
3. Intercept Targets
 - ERIS
 - DEW

B. ENDOATMOSPHERIC

4. Intercept Targets During Endoatmospheric Flight
 - HEDI

A.6.1 DETECTION OF TARGETS

Sensors capable of detecting targets at long ranges in a cluttered environment are being developed as part of the Strategic Defense Initiative and will be tested at USAKA. Therefore range sensors capable of providing "ground truth" for these tests will be needed.

USAKA is located so that it cannot see the boost phase of missiles launched from the US West Coast; we conclude, therefore, that it is unlikely to be involved in boost phase studies and will be concerned only with the midcourse and terminal phases of a ballistic missile trajectory. The midcourse phase is considered here to include Post Boost Vehicle (PBV or "bus") operations in which the PBV maneuvers to place multiple RVs onto trajectories aimed at separate target locations. The midcourse phase lasts for many minutes and is characterized by long ranges, small targets and corresponding weak signals (even any rocket plumes from the PBV are inconspicuous compared to boost phase plumes), and the absence of perturbing events which might be used to distinguish RVs from other objects. The reentry phase is characterized by rapid decelerations (inversely (?) proportional to an object's ballistic coefficient and proportional to atmospheric density), rapid heating (resulting in strong optical signals) and short distances and times to impact. During these phases, discrimination of RVs from other objects, rather than detection or tracking, is ordinarily the source of the most critical sensor requirements.

Discrimination is a difficult problem for several reasons. The first of these is that the number of other objects can far outweigh the number of RVs by factors of tens to perhaps hundreds, implying a strong need for low false alarm rates. The second is that it does not appear difficult to design lightweight objects which will appear at least superficially like RVs. The third is that the sensing and discrimination must be performed in a nuclear environment. Finally, the most clearly robust discriminant, atmospheric deceleration is only available very late in the RV trajectory.

In order to deal with these problems, SDIO research has been focussed on the concept of layered discrimination, in which passive sensors (e.g., LWIR) acquire and track all objects and reject those objects most readily discriminated against. As a second stage, active sensors (e.g., radar, laser radar) are used to perform more difficult discriminations. In the third stages, interactive discrimination methods (e.g., neutral particle beam) are used and, finally, atmospheric deceleration may be used.

The specific planned projects and their needs are discussed in general in the following sections.

A.6.1.1 GBR-X

A.6.1.1.1 Program Description

The GBR-X radar will be installed on Kwajalein to evaluate real time discrimination in high endo and exo. The project objectives should be completed by the end of CY 93 when the radar could become a range asset. The phased array radar will be trainable in azimuth, and along with its agile elevation beam, will have complete hemisphere coverage. The dual array turret face will be covered with an 80 ft diameter radome atop the DCCB rising to a total of 195 ft.

The radar equipment breaks down into three major categories: the dual antenna with the large number of phase shift assemblies and large array plates, the transmitter which has large high power and high-voltage designs, and the electronic cabinet enclosures which house the analog and digital card assemblies and modules. The radar system consists of 4 transmitter groups with 8 travelling wave tubes (TWTs) in a group; dual array with element/phase shifter assemblies contained in "6-pack" and "12-pack" housings; a beam steering unit which drives the individual phase shifters with the appropriate steering commands; a receiver-exciter/test target unit which generates the low level RF signals for distribution to the transmitter and which takes the received energy from the array and converts it to digital form after

two down-conversions; a signal processor which utilizes fast Fourier transforms (FFT), followed by detection circuits to convert the digital signals from the receiver to detected targets and images for further processing by the data processor. The Signal Processor (SP) also includes a high speed recorder which takes the unprocessed received data and records it for post-mission processing, and a timing and control unit which provides the major interface between the radar and the data processor. In addition, the radar has built-in diagnostic software to determine if the unit is operational, which unit is bad if a problem exists, and which of the lowest replaceable units (LRUs) need to be replaced to bring the system back on line. This software is resident in the radar units and controlled by the Radar Test Control Program and associated terminal located in the data processing area.

The Limited Field of View (LFOV) portion of the dual antenna is new for GBR-X compared to the TIR design. It has a multiple element radiating unit driven by a ferrite phase shifter similar to the Full Field of View (FFOV) unit designed for TIR. This design, initiated in the first quarter of CY 1988, will be a continuing effort so as to complete the design, mutual coupling tests, and start of pilot array fabrication in time for the CDR. A parallel effort is in progress to develop a horn for the LFOV instead of a multi element patch radiator. A decision on which approach to use will be made in the 3rd quarter of FY 89 based upon analytical and mutual coupling model tests. Long lead procurement will start prior to CDR in order to make the components available for assembly into the array. It is important that this be a continuing effort due to the large quantity (21,504) of these units. In parallel with this LFOV effort, the FFOV element phase shifter assemblies (EPSA) will continue with building and test of the pilot array. This will verify the design. The procurement of the production quantity will be initiated following the design of the remaining FFOV components.

A.6.1.1.2 Impact to USAKA - GBR-X

Project Office requirements will be insignificant compared to the USAKA planning, funding, and managing a smooth transition to a contributing range sensor. The GBR-X/USAKA transition plan is a separate document.

Siting the GBR-X atop the DCCB will be a logistic challenge. The pure mass of installing the radar 120 ft above ground in addition to installing complex electronics at different levels will stress existing resources.

The technical challenge will be in meeting safety constraints and calibration support. Safety constraints will not only be for personnel but also equipment. It will be necessary to protect airborne instruments and sensors in addition to ground electronics such as the digital microwave system. Calibration support will be required in the near field with precise tracks of a towed target or a near stationary target such as a calibration sphere on a tethered balloon. During dedicated and targets of opportunity (TOO) mission support, the existing USAKA capability for metric and signature data will be sufficient.

A.6.1.2 Ground-Based Surveillance and Tracking System (GSTS)

A.6.1.2.1 Program Description

The USASDC is conducting a technology validation experiment called the Ground-Based Surveillance and Tracking System (GSTS). The experiment is a comprehensive development and test program designed to resolve key technology and functional performance issues associated with exoatmospheric surveillance and tracking sensors. The GSTS works in concert with other Strategic Defense System (SDS) sensors, the Boost Surveillance and Tracking System (BSTS), and the Ground-Based Radar (GBR). Data from the BSTS and the SSTS is used to alert the GSTS, determine the best trajectories on which to launch them, and

direct the attack corridors in which the GSTS is to search. The GSTS remains secure in its underground silo until the track data from the BSTS and SSTS indicate it is needed. It is launched on the trajectory which provides the best viewing position of the actual attack. The GSTS quickly rises above the atmosphere, and the LWIR sensor is deployed and begins to search its assigned attack corridors. It is capable of tracking warheads during their midcourse flight at very long ranges, and, since it is a passive sensor, it can track large numbers of objects. The data gathered by the GSTS is relayed to the ground and is used to distinguish warheads from decoys, establish the trajectories of the warheads, and provide this data to the system's interceptors. The GSTS also directs the search of the GBR which is used to aid the process of distinguishing warheads from decoys. The Phase I of GSTS will be launched from USAKA to demonstrate forward launching into the threat for selective viewing, exploiting synergism with midcourse precommit elements and provides a low cost demonstration and validation of midcourse sensor performance with a low risk development of near operational hardware and software. Critical issues to be resolved in the functional demonstration program are:

1. Functional:

- a. Real time exo discrimination by bulk filtering of the debris,
- b. Sensor to sensor correlation,
- c. Closely spaced objects resolution and algorithm processing,
- d. Support for handover of passive track performance and associated algorithms.

2. Hardware:

- a. Wide field of view LWIR sensor,
- b. High throughput signal and data processing,
- c. Ground based logic and interfaces.

3. Environmental:

- a. Consideration for nuclear background and associated survivability,
- b. Low, hard earth angle viewing.

There are numerous parallel technology efforts that will provide data to the GSTS such as the Utah State's SPIRIT II and APL Midcourse Sensor Experiments, the EXO Discrimination Experiments and Queen Match, and the airborne technology platforms of the Airborne Surveillance Testbed and Cobra Eye.

A.6.1.2.2 USAKA Data Requirements

Mission test planning for GSTS is all preliminary with four missions being considered of which the first three will be prototype flights followed by one integrated system test with flight tests starting in early 1995. The first prototype mission will use a VAFB T00, the second will be a dedicated target and the third a dedicated target with a dual GSTS launch. The integrated system test will be a dual GSTS launch with a dedicated target integrating some tactical hardware such as ERIS or HEDI derivative. In each mission the payload and delivery system must be integrated into the launch support and range support equipment. Mission simulation and flight readiness testing will support launch operations. There is a requirement for

recovery of the payload in the BOA. Refurbishment of the payload may be accomplished at USAKA. The following are the more stressing instrumentation and communication requirements.

1. TM encrypted data rate of 10 Mbps.
2. Command uplink, encrypted and encoded, for two simultaneous GSTS probes.
3. Simultaneous flight safety destruct capability.
4. A 20-40 GHz ground communication data transmission capability to simulate a tactical pointing system.
5. GPS data for navigational performance.
6. Trajectory state vectors through endo for recovery support in the Wake Island area.

A.6.1.2.3 Impact to USAKA

GSTS' major challenge for support will be in the magnitude of the data links. The flight safety solution will not be stressing (compared to a HEDI class vehicle) except for the simultaneous launches. If GBR-X is on schedule as a range sensor and the safety software incorporated, it could easily support the multi-object requirement. The downlinks of two complex data streams will require additional TM capability and ground data transmission. Recovery of the two payloads exceeds the range capability with outside support (Navy or contractor) required. With proposed launches from Omelek, and the Mission and Launch Center on Meck, an underwater fiber optics data link will be required.

A.6.1.3 Exoatmospheric Discrimination Experiment (EDX)

A.6.1.3.1 Program Description

The Exoatmospheric Discrimination Experiment (EDX) has the broad objectives of evaluating discrimination techniques on midcourse objects and background using exoatmospheric passive LWIR sensors. A growth potential for the experiment is subsequent kill assessment in DEW programs. EDX will be launched from PMRF, Barking Sands, HA, with no payload recovery currently planned.

A.6.1.3.2 USAKA Data Requirements

KREMS data will be required to correlate EDX data. Real time radar discrimination techniques, along with perhaps optics inputs, will be required.

A.6.1.3.3 Impact to USAKA

EDX will not impact USAKA as all requirements appear within the range capability.

A.6.2 Airborne Optical Adjunct (AOA)

A.6.2.1 Program Description

The Airborne Optical Adjunct (AOA) Experimental System is a modified version of the FAA certified Commercial 767 jet transport. External modifications include the LWIR sensor located in a faired cupola located on the top of the forward fuselage and ventral fins added underneath the aft fuselage. The cabin of the aircraft will be configured with test consoles, test equipment and test instrumentation

required to perform the AOA missions. The cockpit and flight controls remain unchanged from the basic 767 design. Aircraft performance summary:

1. Maximum Speed - .86m/360 KIAS
2. Operational Speed - .76m
3. Maximum Altitude - 50,000 ft.
4. Operational Altitude - 45,000 ft.
5. Maximum Gross Weight - 317,000 pounds
6. Operational Gross Weight - 251,500 pounds
7. Operational Landing Weight - 197,500 pounds
8. Maximum Endurance - 11 hours
9. On Station Endurance - 4 hours

The AOA program has two general subsets. The first is the Basic Program and the follow-on is the application as an Airborne Surveillance Testbed (AST). Although the AOA mission objectives are classified, the general program objectives are:

1. Validate functional performance through long range acquisition, discrimination and accurate track and handover.
2. Support sensor technology for boost, midcourse and terminal defense.
3. Provide testbed for advanced technology of:
 - a. Long wavelength-infrared sensors.
 - b. Real time, on-board data processing.
 - c. Integrated components on airborne platform.
 - d. Target signature and background
 - e. Aero-optics effects and controls.

The AST LWIR surveillance capabilities are:

1. Accurate track, discrimination, and handover of real time downlink of track data with long track times.
2. Measurement capacity with state-of-the-art precision for two (2) midcourse LWIR wavelength signatures (long & medium) and three for boost and reentry signature (long, medium, and short bands) with on board capability for raw and processed sensor data recording.
3. Operational considerations of stable platform with GPS navigation and SATCOM communications, mobile basing with long on-station times, and high altitude operation.

A typical AOA mission activity would begin with the calibrations and possibly cooling of the sensor in Seattle. One day is allowed for the ferrying of the plane from Seattle and post flight operations and servicing. If the sensor was not cooled in Seattle, two days are required to totally cool the sensor and module. At this point, the experimental system has a seven(7) day standby capability with dry runs and simulations included in this time. The test will be conducted in one day. Eight (8) hours are required for system initialization, checkout, and final flight preparations. The flight can last from 4 to 7 hours. Post flight operations will take 4 hours with an initial report available in 4 hours. Two days is the nominal time for post- mission servicing and ferry preparations with a 48 hour report available. The aircraft will be returned to Seattle.

A typical AOA time line would contain the following functions:

Time (minutes)	Function
T-154	AOA takeoff; begin climb to 40,000 ft.
T-139	Begin cruise at 40,000 ft to primary site.



T-94	Loiter, or cruise to alternate site (45 minutes to 1.5 hrs)
T-49	Begin climb to 44,000 ft
T-39	Achieve altitude of 44,000 ft. Open port, uncap and deploy sensor checkout system
Prior to T-34	IAR initialization
T-34	Turn as required for star scan; IAR update; background data. Turn as required to achieve IP at T-0
T-10	Continue path to IP at T-0
Hold (0-2 hours)	Hold for launch delay; update IAR as required Maneuver as required to handle delay and still achieve desired viewing point
T-0	Flight path through IP at T-0 for on time launch
(Target launch)	Climb to final viewing altitude
(T+7)	Level off, trim for heading/attitude/mach
T+15	Initiate scan; initiate target generator; acquire target. Hold heading/attitude/mach

T+25	End of observation of targets; turn off object generator. Continue viewing stars if desired. Slow bank equal to or less than 5 degrees to acquire star field.
T+30	Begin descent
	View stars as desired
	Level off, trim for heading/altitude/mach
T+35	Stow and cap sensor/close port and return to base
T+95	Land at USAKA

The AOA airplane is equipped with all standard communication, navigation, and meteorological instruments. The instruments that directly support mission functions are the UHF com receiver and transmitter, the UHF SATCOM receiver and transmitter, the GPS transmitter and receiver, and the weather radar. Additionally, the aircraft is equipped with telemetry data and voice links and an L-Band transponder having both Mode A, which is for aircraft identification; and Mode C, which includes airplane altitude reporting. This system utilizes a 1030 MHz center frequency. This particular aircraft is equipped with a redundant system with dual transponders and dual fuselage mounted blade antennas. The L-Band transponder installed conforms to ARINC 730 specifications. The high accuracy position information will be provided by a GPS and consists of a receiver/processor and an antenna which will be mounted externally on the airplane's cupola. This system receives and processes the L-Band signals generated by GPS satellites to generate the very accurate space positioning data required in the AOA technology demonstrations.

A.6.2.2 USAKA Data Requirements

Metric data are to be acquired by USAKA and midrange sensors on the incoming target complex and used to provide real time state vectors for uplink to the AOA airplane via Mobile Support Van (MSV) and for data recording records for Honolulu Data Reduction Facility (HDRF) post flight analysis. The state vectors for the target complex are to be recorded at the ICC at a data rate of at least 1 state vector per second. Target data for targets of opportunity (TOO) must be coordinated with the primary users so that maximum utilization of data can be realized. Radar data are to be acquired in real time from acquisition to impact or demise time for all hard objects (RV's, balloons, PBV, tank and replica decoys) in the target complex, and for as many chaff clouds as possible. Transponder data are required for each beacon tagged object (up to three) and skin tracking is required for all other objects. In addition IRV data are to be acquired from WTR and midrange radars. Special IRV's are required for TOO flights.

Target complex data to include booster liftoff and thrust termination times in UTC (with less than 5 minute time delay), the IRV from WTR (Special IRV data, derived from guidance system data, are required for TOO flights) and midrange (with less than 1 minute time delay), and USAKA and midrange sensor metric data are required to be relayed to the AOA airplane in real time (within 3 seconds). USAKA and midrange data for each object are required as state vectors in the Meck Battery Origin (MBO) coordinate system at a data rate of up to 10 state vectors per second. The data must be identified with a unique object code. The data must also be identified with an "active track" indicator specifying whether the object is in closed loop track. The real time requirement for sensor module recording selection is to have an angular accuracy of 0.25 mrad as seen by the AOA sensor from target acquisition through 20 km target altitude. Not all objects need to be tracked simultaneously. The radar tracking plan shall be coordinated with AOA sensor module recording plan for each flight.

Data from the midrange radars will be sent to USAKA via the high speed data link. This translates into a 1 standard deviation minimum position accuracy of 600 meters at 2400 KM radar acquisition range and a maximum position accuracy of 925 meters at 3700 KM acquisition range.

To perform quick-look handover evaluation, data are needed within 24 hours around the high and projected low handover altitudes (unless object has already demised by the projected low handover altitude). The object type is dependent on individual mission requirements. Generally, data will be needed for the RV's, heavy replica, and light replicas. Filtered and fitted trajectory data are needed to a one sigma accuracy of 190 meters at high handover altitude and 80 meters at projected low handover altitudes. Additionally, metric data will be sent from the AOA MSV to the ICC. A teletype (TWX) message containing a summary of the metric data acquired is desired within 12 hours of flight. This message should contain preliminary estimates of sensor coverage, acquisition times, range and altitude of tracking spans, number and type of objects tracked, description of tracking difficulties, any test abnormalities, etc.

A minimum of 250 seconds of "good" boresight radar tracking above an altitude of 20 km is mandatory for all hard objects (RV's, heavy replicas, light replicas, PBV, tank and as many balloons as possible) in the target complex and as many chaff clouds as possible.

Transponder tracking is required for each beacon tagged object (up to three) and skin tracking for all others. These data must be acquired in a series of uninterrupted ten second (minimum) periods spaced throughout the exoatmospheric flight phase. Approximately 40 seconds of tracking data are required below target altitude of 150 km through 20 km to provide a filtered and fitted endoatmospheric trajectory. Off-boresight metric data are also required from as many target complex objects (balloons) as possible during the exoatmospheric and endoatmospheric flight phases. Magnetic tape(s) containing radar trajectories for all tracked objects are required one week after flight. These data will be listed and correlated with Universal Time

Coordinated (UTC) at a rate of one sample per second from lift-off plus 1200 seconds to an object altitude of 25 km. A summary report of the multisensor support operation including sensor coverages, data acquisition anomalies, and radar configuration and tracking sequences will be provided. The report should include HDRF sensor data, as well as RADOT and super RADOT photographic data.

The radars shall acquire, search, (if necessary), and track the target following receipt of the AOA handover message consisting of a target state vector and covariance matrix (both in MBO coordinates) projected to the high handover altitude. The radar system shall record trajectory data (including time) and monitor tracking performance. As the target descends through the EOT handover altitude, a second handover message will be generated by the AOA and projected to the low handover altitude. Depending on mission objectives, the tracking radar may (1) continue tracking the same object and record pointing and trajectory data for later analysis, (2) break radar track and reacquire the same object at low altitude based on the second AOA handover message, or (3) break radar track and acquire a different object based on the AOA handover message. The post mission handover report shall describe radar pointing performance and assess the accuracy of the handover messages. It shall include:

1. Times of handover message arrival at USAKA computers and radar facility.
2. Radar slew start and stop times.
3. Target acquisition time and track time.
4. Pointing of radar versus time.
5. Pointing error at initial acquisition.
6. Details of any acquisition searches performed.

7. Estimation of error (with uncertainties) in each AOA handover message.

To perform handover evaluation and algorithm validation, data are needed from acquisition until object demise or the projected low handover altitude. The object type is dependent on individual mission requirements. The data are desired two weeks after each mission. Generally, data will be needed for RV's, heavy replica, light replicas, and balloons. The balloon data can be obtained from off bore-sight tracking data and is required 135CD following flight. Data is needed to the following accuracies at the high and projected low handover altitudes. Accuracies at the high handover altitude should be 120 meters (1 sigma) and 55 meters at the low handover altitude. For metric discrimination, filtered and fitted trajectory data are needed for the RV, heavy replica, and light replicas. The accuracy requirement is required with respect to an inertial or earth fixed coordinate system. The accuracy is needed at the specified altitude, although data is desired for object altitudes from 200 km to 20 km.

Optics signature data are required consistent with daylight conditions existing during each AOA mission. Identification analysis and radiant intensity estimation analysis are requested.

Meteorological support is required to facilitate both pre-flight AOA positioning for observation and post-flight analyses of target complex environmental factors. Severe weather advisories are required as far in advance of each AOA mission as practical. Separate estimates of the above cloud and cloud cover parameters are to be furnished above the 45,000 ft. AOA platform altitude for a 500 nautical mile grid about Kwajalein. These estimates are for four (4) approximately 500 by 500 nautical mile segments. Post flight observations for the area below the target complex flight path, extending from 1000 nautical miles downrange from the impact area at USAKA and outwards to 2000 nautical miles on each side of the trajectory, represented by a grid system approximately 4000 x 6200

nautical miles, dubbed the "extended" area. This extended area shall be subdivided into ninety-six (96) approximately 500 by 500 nautical mile segments, providing contiguous coverage of the total area. Supporting synoptic weather data, such as satellite and weather radar photography used in the cloud cover and temperature estimating process, are required for post-flight analyses.

A.6.2.3 Impact to USAKA

A severe limitation will be the number of objects in track. It will be essential for USAKA to have intermittent track on many objects to meet the requirements. The handover and classification of many of the objects presents a significant risk in real time. Fortunately, AOA experimental system is not a real time experiment such that the sorting of all objects (RV's, heavy replicas, light replicas, balloons and chaff) can take place post mission as multiple intermittent track files are merged. USAKA post mission effort will be significant for AOA tests.

The USAKA optical signature capability is very limited. The only capability exists in the near terminal end such that optical aircraft (ARGUS, HALO and Cobra Eye) should support the dedicated missions.

The challenging USAKA support for AOA will be logistically. In spite of planning with a "fly away kit", their own ground station, and optical calibrations in Seattle; unplanned for support is inevitable (like running out of LN 2). USAKA will support AST long after the AOA Experimental System objects are realized. It is practical to plan on a more extensive logistic base than currently available.

A.6.3 INTERCEPT

A.6.3.1 ERIS

A.6.3.1.1 Program Description

The ERIS Functional Technology Validation (FTV) Program will validate concepts and resolve critical issues associated with midcourse intercept and non-nuclear kill of re-entry vehicles as an element of the overall Strategic Defense Initiative. Flight test operations will use dedicated target RVs launched from Vandenberg Air Force Base. The mission of an operational system is to intercept Intercontinental Ballistic Missile(ICBM) and SeaLaunched Ballistic Missile (SLBM) threats by means of exoatmospheric homing with non-nuclear intercept.

A total of four ERIS flight test vehicles will be built for the FTV program. The basic FTV contract requires three flight tests consisting of intercept and destruction of the target RV. Up to five additional flight tests may be required contingent on contract options exercised by USASDC. The FTV subsystem to be tested on Meck Island consists of the Launch and Ground Support Equipment (LGSE) and the Air Vehicle (AV). The LGSE segment consists of the ground-based support equipment required for pre-mission checkout, countdown, launch, and commanding of the Air Vehicle. The Mission Control segment of the LGSE also generates and updates AV target data and provides flyout and intercept data to the AV in flight via the USAKA Command Control Transmitter. The Air Vehicle consists of a first and second stage booster with interstage, Flight Termination System Adaptor (FTSA), Booster Adapter (B/A), and Kill Vehicle. The Kill Vehicle (KV) contains the infrared seeker subsystem, Avionics Package (AP), Propulsion and Reaction Control System (PRCS), Electrical Power Distribution System (EPDS), status-of-health instrumentation,

communications and tracking equipment including a C-Band Transponder and Global Positioning System (GPS) translator, and a Kill Enhancement Device (KED).

Target vehicle state vector and position data will be provided in real time to the LGSE by the GPS ground station. The LGSE will generate an intercept solution and launch the ERIS vehicle at an appropriate time to effect an intercept. Following second stage burnout and separation, a handover message will be transmitted using the Kwajalein Command Control Transmitter. After booster adapter separation, the KV will use its divert thrusters to establish and maintain a collision course to the target RV. Inputs from the IR seeker will command divert thruster firing during the final phases of the "end-game". The KED is deployed shortly before intercept. The Observer Package (OP) provides signature and phenomenology data to ground-based telemetry stations via telemetry link.

Several target configurations will be used during the FTV program. Balloons or other objects may also be used to enhance the target suite on some missions. A demonstration of intercept and non-nuclear kill will be the objective of each mission. The intercept parameters (range, altitude, aspect angle, closing velocity, V-gamma and target type) are selected to provide data on resolution of the key issues identified for the flight test and are mission-dependent.

A.6.3.1.2 USAKA Data Requirements

Each flight test is designed to obtain functional data on designated key issues and evaluate performance of the FTV system on a dynamic flight-test environment. The trajectory profile selected for each mission is consistent with the concepts set forth in the USAKA Range Safety Manual. In general, USAKA requirements include metric data, telemetry data, GPS tracking data, ground and flight safety monitoring and control, and voice intercommunications. The range instrumentation also provides RF services for flight safety, data

uplink and downlink telemetry, and interface with the Western Space and Missile Center (WSMC) for the processing of midrange (Kaena Point) target data.

In flight interfaces with the USAKA Range Equipment and the Air Vehicle are accomplished through the following radio-frequency (RF) links:

1. Flight safety command control from the USAKA Range Safety System (USAKA RSS) and uplink data from the Mission and Launch Control (M&LC) via USAKA RSS (CCT).
2. C-Band Transponder response to interrogation by USAKA tracking radars.
3. Real-time Global Positioning System (GPS) position solution via Translator (S-Band) to both air vehicle and target vehicle.
4. PCM telemetry data to Ennylabegan Telemetry Station (ETS).

USAKA sensors, facilities and personnel will be required as follows:

1. Real time mission support .
2. Pre-mission test planning and integration support .
3. Pre-mission target of opportunity support is desired.
4. Post-mission, data reduction and evaluation support is required.
5. USAKA sensors are required for target state vectors. The priority is mandatory.

6. The other USAKA sensors are required for the interceptor trajectory track.
7. Data is to be provided to the M&LC in real time, via the RDS.
8. USAKA radar are required for tracking the Observer Package.
9. GPS metric tracking data is required through the end of the program. Data from the GPS metric tracking system is mandatory for both the Air Vehicle and the Target Vehicle. The GPS metric data processed by the Ennylabegan TPS will be used to formulate an uplink message to be sent to the Air Vehicle.
10. Interrange Vector (IRV) data is required to be obtained by the transponder track of the RV after thrust termination of the target vehicle third stage booster. The IRV will be measured by WSMC radars and transmitted via teletype to USAKA. The IRV is required by the M&LC as input data for both dedicated and opportunity missions. For targets of opportunity, the IRV can be made on the tank in lieu of the RV.
11. Target vehicle launch and separation (balloon timer start) times along with selected target vehicle telemetry data are required to be transmitted to Meck Island via data circuit.
12. Mounting accommodation for an S-Band parabolic dish antenna will be required on the roof of the MICB. The 3-foot dish antenna will support the pre-mission checkout of the Air Vehicle. The dish will be mounted at the 15-foot level on the MICB roof antenna tower. It weighs approximately 50 pounds.
13. IRIS/HALO aircraft in addition to the AOA testbed may be required.

14. Real time test data requirements include Track Files sent via the RDS to the LMSC MicroVAX Computer. The track files will correspond to a combination of sensor, transponder or skin track.

A.6.3.1.3 Impact to USAKA

The ERIS FTV will stress the total capability of USAKA. The real-time requirement of telemetry (increased data rates, band width, links, encryption), track files, safety system, GPS, radar accuracy requirements, and communications are all demanding and exceed existing capability. Compromises from the desired requirements will have to be made. The USAKA critical issues where compromises cannot be made (directly affect the objectives) are in the area of GPS and RSS. These two developments directly affect the timely success of ERIS. However, since these new USAKA capabilities support multiple SDI programs, their implementation will effect multiple programs.

A.6.3.2 DEW

A.6.3.2.1 Program Description

STARBIRD is a portion of the STARLAB experiments using the Shuttle. The tests include the launching of boosters off Wake Island with the tracking and ultimate DEW engagement and destruction. Planned in late 1994 is a neutral particle beam (NPB) experiment aboard an orbiting platform.

A.6.3.2.2 Impact to USAKA

DEW could become a very big challenge for USAKA in follow on phases to SDS. In the near term, a number of ground sensors appear necessary to support NPB experiments such as gamma neutron detectors that can measure the reflected energy off a target at Kwajalein,

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detectors to measure the orbiting platform to answer the question, "how far does NPB penetrate the atmosphere," and having KREMS sensors measure the kinetic effects of particles on a target.

A.6.4 HEDI (XP-BTI)

A.6.4.1 Program Description

HEDI was not selected as part of Phase I SDS. However, there was a requirement that HEDI keep pace with Phase I. This resulted in a restructured program that is currently being defined. The KITE validation program, or the three (with a fourth test option) flights at WSMR, is to remain intact to be completed in 1991. Simultaneously, an Experimental Prototype (XP) phase will commence for testing of two vehicles at USAKA in mid 1993. The XP program is constrained by KITE successes. The significance of the XP program is the propulsion development which will be of a new high performance but relatively low risk (cylindrical) two stage configuration. The first USAKA launch will be a propulsion test vehicle with the second test an all up vehicle. The kill vehicle will also be new undergoing a weight reduction from 800 lbs in the KITE program to 400 lbs in XP. Simultaneous with the XP test program will be a new competition for the Baseline Technology Interceptor (BTI) which will support FSD. The XP propulsion is envisioned to be a near tactical design such that the large investment in propulsion will be its qualification. The goal of the kill vehicle in FSD is 200 lbs. The BTI program has a qualification flight test phase at USAKA commencing in late 1995. This effort could include multiple and remote launches. As such, GBR-X would be essential for range support.

A.6.4.2 USAKA Data Requirements

The broad XP test objectives are all the KITE objectives (window cooling, separation, kill, etc.) but at tactical velocities. A

precommit metric accuracy of better than 100 m absolute is required on the target. Additionally, periodic uplink updates will be required to better accuracies. A flight safety solution for the high velocity vehicle from Meck is essential. Optical and signature kill assessment of the target is desired.

A.6.4.3 Impact to USAKA

The XP program will stress the safety and metric systems. The midcourse IRVs will be an essential input. Current (or planned) USAKA metric capability will not meet XP requirements. The GBR-X cannot be relied upon to be a qualified range sensor at this time. The two alternatives for USAKA to support the XP metric track requirements are either GPS or long baseleg multilateration. GPS requires translators in both the target and the interceptor while multilateration requires a relatively precise metric tracking radar at Wake Island.

The Range Safety System (RSS) should be fully qualified by this time. The question is what sensor input can track this very high acceleration vehicle from the deck. Additionally, an uplink for target updates is required. There will be no stressing TM, optical or signature requirements. The exact BTI program requirements are currently being defined and will exceed many USAKA sensor capabilities.

A.7.0 INTELLIGENCE MISSION REQUIREMENTS

The exoatmospheric and endoatmospheric intelligence gathering and surveillance of foreign launched ICBMs in flight is an important national security function. The types of observations required for this function are in many ways similar to those required for domestic RVs in mid-course and reentry. While foreign ICBM flight paths which can be observed from USAKA are infrequent, they still require a high state of readiness to respond rapidly and track unannounced foreign ICBMs while in flight. Table A.7 lists the required measurements to accomplish the mission objectives for foreign ICBM surveillance.

Both exoatmospheric and endoatmospheric data collection are required when possible. Section A.7.1 through A.7.4 describe the information needed from exoatmospheric and section A.7.5 through A.7.7 describes the information needed from endoatmospheric surveillance.

A.7.1 MISSILE DETECTION AND IDENTIFICATION

The primary objective of this mission is to detect and track, in flight, foreign ICBMs in range of USAKA sensors after the payloads break the horizon. USAKA lies in the launch corridor which is infrequently used by a foreign country to perform ICBM test missions. Since any new launches would come over the horizon only minutes after launch, the detection and tracking operations must be manned during periods of interest and kept in a high state of readiness.

The nature of the launch alert notification and collected data is such as to warrant special communication requirements of secure voice and data transmission. A dedicated secure 9600 baud data link is required to pass alerting information and state vectors to tracking radars and other sensors. Secure voice is required for alerting and real-time discussions of the event.

TABLE A.7

INTELLIGENCE MISSION REQUIREMENTS

Objective: Detect foreign ICBM tests during mid-course and early reentry, and collect signature and metric data and determine performance capabilities.

A. EXOATMOSPHERIC

A.7.1 **Missile Detection and Identification**
- Object Acquisition and Count
- Object Identification
- Signatures
- Trajectories

A.7.2 **Signature Acquisition**

A.7.3 **Reentry Point**

A.7.4 **Reporting Signature and Trajectory**

B. ENDOATMOSPHERIC

A.7.5 **Metric Data Acquisition**
- Reentry Dispersion
- Impact Point

A.7.6 **Reentry Signature**
- Body
- Wake
- Angle of Attack History

A.7.7 **Report Signature and Performance Capabilities**

When an alert is received, the detection and tracking sensors must search the uncertainty volume, detect all possible ICBM targets at ranges up to 3300 kilometers, and determine if the object in flight is the foreign ICBM, and place it in track. For non-historic launches the required search is a horizon scan of a 75° azimuth sector. It is desirable to also have exoatmospheric optical observations for trajectory determination and for wide area search.

Another of the intelligence gathering objectives is to detect and track all objects in the complex for overall count. It is desirable to have autonomous search and acquisition for tracking multiple objects simultaneously. The objects must be identified and located in real-time to within best obtainable range and angle resolution. Some of the reentry vehicles may have on-board sensors and it would be desirable to search the possible frequency spectrum to receive telemetry signals to determine which are active (instrumented).

The trajectory prediction of the objects is desirable. When monitoring the foreign reentry vehicles it is important to watch for the resulting pattern of RVs, possible decoys and support modules. Metric measurements are required to perform analysis on the pattern of objects in the complex relative to each other. The measurements should be capable of determining and/or evaluating the performance of the deployment mechanism by examining relative object placement rather than absolute trajectory placement. Analysis of trajectory measurements should provide the best obtainable accuracy (object-to-object).

It is important to learn as much as possible about the RV flight characteristics and stability. While wideband signature data and range/cross-range images are the most valuable information, metric and narrow-band data is also valuable.

Object identification depends greatly on the ability to image the RVs. The ideal imaging sensor should be capable of imaging an object (similar in size as a domestic RV) which provides adequate range and cross-range resolution.

A.7.2 SIGNATURE ACQUISITION

For this case, where the RVs could be new and of an unknown configuration, there will be no data base of exoatmospheric signatures. The requirement then is to collect signature data which can provide the best possible resolution given the conditions and range of the foreign vehicle. Coverage on multiple objects, including closely spaced objects, must provide adequate signature data to determine and analyze performance and perhaps recognize new and/or anomalous behavior. Signatures across the entire electromagnetic spectrum are desired.

A.7.3 REENTRY POINT

The determination of reentry point is important in order to determine possible anomalous behavior from pierce point to impact (if observable from USAKA or by an air platform). No accuracy requirements are stated, but data from these missions should be processed to the limit in order to achieve the best possible pierce point and subsequent trajectory determination.

A.7.4 REPORTING SIGNATURE AND TRAJECTORIES

It is also required to report and transmit all information collected on the foreign RVs to the proper authorities for intelligence analyses. The nature of the collected data is such as to warrant special communication requirements of secure voice and data transmission. Full sets of image and metric data of the objects must be processed and transmitted as quickly as possible.

A.7.5 METRIC DATA ACQUISITION

The measurement of reentry dispersion of the RVs is required to determine flight deviations during reentry from a predicted trajectory. The observation of unusual deviations from a predicted trajectory could be used to infer performance capabilities of the foreign RV. No accuracies are stated, but best possible are needed so that the reentry trajectory can be analyzed for anomalies.

Accurate impact point location and timing is required for intelligence analysts to determine possible target aim point accuracy of foreign ICBMs relative to the flight trajectory plane. Such determinations may be possible from an airborne platform sensor.

A.7.6 REENTRY SIGNATURE

Reentry signatures are part of the profile that is required in the accumulation of a data base of foreign RVs. Such information is important for potential target discrimination and defensive weapons development. Full spectrum optics in addition to RF is desirable from pierce point to 50,000 feet altitude.

The RV body generates unique signature characteristics during reentry. Sheathing altitude, sheathing effects and boundary layer transition are examples of body observations made during reentry. Body signatures should be separated from the wake signature. Data must be collected for analysis of wake characteristics such as wake onset altitude, length, and wake velocity profile. It is also important to determine if any unusual events or objects are deployed.

The angle of attack history and trajectories must be determined for evaluating the foreign RV performance and for interpreting other observations.

A.7.7 REPORTING SIGNATURE AND PERFORMANCE CAPABILITIES

It is also required to report and transmit all information collected on the foreign RVs reentry signatures and performance metrics to the proper authorities for intelligence analyses. The nature of the collected data is such as to warrant special communication requirements of secure voice and data transmission. Full sets of image and metric data of the objects must be processed and transmitted as quickly as possible.

A.8.0

SPACE SURVEILLANCE MISSION REQUIREMENTS [NFLS, DEEP SPACE, SOI]

The exoatmospheric surveillance of foreign and domestic satellites is an important national security function. The types of observations required for this function are in many ways similar to those required for RVs in mid-course. However, the requirement to respond rapidly and track unannounced new foreign launches adds the requirement of high readiness. Table A.8 lists the required measurements to accomplish the mission objectives for space surveillance.

Both "near space" launch and orbital data and deep space ascending and orbital data are required. Section A.8.1 through A.8.4 describe the information needed from "near space" and section A.8.5 through A.8.8 describes the information needed from "deep space" satellite surveillance.

8.1 DETECT NEW FOREIGN LAUNCHED SATELLITES

The primary objective of this mission is to detect new foreign launched satellites. USAKA lies in the launch corridor most frequently used by the USSR. Approximately 50% of new satellites are visible from Kwajalein on their initial orbit. Since the new launches come over the horizon only 20 minutes after launch, the detection and tracking operations must be manned 24 hours a day and kept in a high state of readiness.

The nature of the collected data is such as to warrant special communication requirements of secure voice and data transmission. A dedicated secure 9600 baud data link to the NCMC is required to pass alerting information and state vectors to tracking radars and Space Command. It is also used to update the catalog needed to differentiate between new and existing objects. Secure voice is required for alerting and real-time discussions of the event. Secure

Table A.8
SPACE SURVEILLANCE

Objective: Determine and maintain orbits of space objects, determine mission, capability, and status of satellites.

A. NEAR EARTH

1. Detect New Foreign Launch Satellites
2. Determine Accurate Orbits of High Interest Objects
 - New foreign and domestic launches
 - Decaying objects
 - System calibration satellites
3. Space Object Identification (SOI)
 - Mission of satellite
 - Imaging to determine configuration
 - Motion and stability
4. Report Location and Configuration Changes

B. DEEP SPACE

5. Detect All Deep Space Injections
6. Determine Accurate Orbits of all Objects
7. Space Object Identification (SOI)
 - Mission of object
 - Imaging to determine configuration
 - Motion and stability

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flash precedence autodin access is also required to pass data to and from other sensors and as a back-up to the dedicated link.

When an alert is received the detection and tracking sensors must search the uncertainty volume, detect all targets larger than 1 square meter at ranges up to 4700 kilometers, and determine if the object is the newly launched satellite, and place it in track. For non-historic launches the required search is a horizon scan of a 75° azimuth sector. It is desirable to also have exoatmospheric optical observations for angle calibration, orbit (trajectory) determination and wide area search.

A.8.2 DETERMINE ACCURATE ORBITS OF HIGH INTEREST OBJECTS

For the space surveillance mission, the major task is to track and provide accurate metric data on "near earth" objects of high interest. These include new foreign and domestic launched satellites, decaying satellites, space surveillance system calibration satellites, maneuvering objects, and objects to be imaged.

This requires accurate track and real-time metric data collection. The methods of data collection must resolve to within 15 meters in range and 200 microradians in angle.

The nature of the collected data is such as to warrant special communication requirements of secure voice and data transmission.

It is desirable to also have exoatmospheric optical observations for angle calibration, orbit (trajectory) determination and wide area search.

A.8.3 SPACE OBJECT IDENTIFICATION (SOI)

The objective of this mission task is to learn as much as possible about the mission of the satellite and its status. While wideband signature data and range/cross-range images are the most valuable information, metric and narrow-band data is also valuable. High elevation passes which allow viewing the earth facing side of the

satellites are particularly valuable and require sensors capable of tracking at high azimuth rates.

The nature of the collected data is such as to warrant special communication requirements of secure voice and data transmission. Any changes in orbit or cross-section must be reported immediately. Images of objects must be processed and transmitted within one hour of a pass and full sets of data (metric, narrow band, etc) transmitted within 12 hours.

One of the main tasks is to determine that the correct object is being tracked. On new launches the payload(s) and tank(s) must be identified. When acquisition is from an element set care must be taken not to acquire other known objects. Metric and narrowband signature data are used for identification. It is also required to monitor motion changes and small orbit changes which are important to intelligence analysts.

Telemetry monitoring from space objects is required to provide information useful for the discrimination of tanks from payloads or to tell if a payload is still active.

Space object identification depends greatly on the ability to image the satellite. The ideal imaging sensor should be capable of unambiguously imaging an object 20 meters long rotating at 1 rad/sec at a range of 1000 kilometers with a resolution of 12-15 cm in range and cross-range. Collection of image and metric data is required up to ten times a day. Description (characterization) is required for such motions as angular momentum vector orientation, precession angle, precession rate, spin rate, etc.

A.8.4 REPORT LOCATION AND CONFIGURATION CHANGES

It is also required to monitor motion changes and small orbit changes which are important to intelligence analysts. Such information is critical to national security and must be reported immediately to the Space Command. The nature of the collected data is such as to warrant special communication requirements of secure voice

and data transmission. Images of objects must be processed and transmitted within one hour of a satellite pass and full sets of data (metric, etc) transmitted within 12 hours.

A.8.5 DETECT ALL DEEP SPACE INJECTIONS

This data collection task is similar to that for "near earth", but quite different in detail due to the far range (resulting resolution) and the slower time scale on which events occur. The objective is to detect and track all deep space objects of significant cross-section. It is desirable to track objects as they ascend into orbit.

Measurement requirements are to detect targets at 40,000 kilometers while searching at a rate of 250 square degrees per hour.

The nature of the collected data is such as to warrant special communication requirements of secure voice and data transmission. Any changes in orbit or cross-section must be reported immediately. Images of objects must be processed and transmitted within one hour of a pass and full sets of data (metric, narrow band, etc) transmitted within 12 hours.

It is desirable to also have exoatmospheric optical observations for angle calibration, orbit (trajectory) determination and wide area search.

A.8.6 DETERMINE ACCURATE ORBITS OF ALL OBJECTS

Another task of the deep space surveillance mission is to keep an accurate catalog of the orbits of all deep space objects, both new and old. It is highly desirable to reduce the duration and number of tracks required to monitor the constantly increasing number of deep space objects. Because the deep space orbits are more stable than near earth orbits, the payoff of high accuracy in reducing the required track update rate is also more significant than for near earth objects. It is desirable to have better range resolution for

deep space. It is also desirable to have exoatmospheric optical observation capability.

Previously described communication needs are required but in addition, a GPS receiver is required to obtain ephemeris data for the GPS satellites which are required targets for ionospheric calibration.

A.8.7 DEEP SPACE OBJECT IDENTIFICATION (SOI)

Essentially the same objectives and tasks described above for "near earth" SOI apply to "deep space" object identification. The main task is to differentiate between payloads and tanks on new launches, find the correct objects in densely populated regions of the geosynchronous belt, differentiate between active and inactive payloads, and contribute all possible information on the mission of the payload. A combination of metric and signature data is required to meet these objectives.

Small maneuvers must be recognized and reported immediately. Careful examination of the signature data and comparisons with previous data on the same object or previously imaged objects are performed to: 1) help in the object identification, 2) reveal body or solar panel orientation changes, and 3) determine whether the object is stable.

The monitoring of transmissions from the object is required to differentiate between payloads in clusters or between active and inactive objects.

More specific information is needed on the size, shape and mission of deep space objects. This information requires better range resolution. Space object identification depends greatly on the ability to image the satellite. An additional problem is that many objects in geosynchronous (24 hour) orbit are also stabilized so there is neither real rotation nor relative motion to produce the doppler shifts required for radar imaging. New methods are required to perform "deep space" object imaging.

A.8.8 REPORT LOCATION AND CONFIGURATION CHANGES

It is also required to monitor "deep space" object motion changes and small orbit changes which are important to intelligence analysts. Such information is critical to national security and must be reported immediately to the Space Command. The nature of the collected data is such as to warrant special communication requirements of secure voice and data transmission.

A.9.0

PHYSICAL PHENOMENA AND SCIENTIFIC MEASUREMENTS

In addition to the other reentry vehicle or satellite tracking missions, USAKA participates in missions to measure basic atmospheric and terrestrial physical phenomenology. USAKA participates in these missions largely because of the existence of its unique sensor capabilities rather than its location at the end of the Western Test Range. However some activities such as supporting shuttle missions are related to its distant geographic location (~8000 miles from Cape Kennedy) rather than its precise location. Isolation is also a desirable attribute for those tests requiring sounding rockets but several other locations (WSMR for example) could meet this requirement.

The types of activities that are included in this category of tests are summarized in Table A.9. These will be discussed in more detail in the following paragraphs.

A.9.1 DNA IONOSPHERIC MEASUREMENTS

The objective of DNA is to understand the effects of nuclear bursts on the transmission of RF signals. Particular measurements that are desired are single target measurements of VHF, UHF, and S-Band. Desired measurements are simultaneous VHF and UHF collection of in-phase and quadrature data at 300 Hz. Also desired is Coherent In-phase and quadrature data collection at S-Band at 100 Hz. Typical measurements are needed once every two years for a time period of up to thirty days.

A.9.2 NASA IONOSPHERIC MEASUREMENTS

As part of the CRRES project, NASA desires VHF, UHF, and S-Band measurements in order to measure the disturbances in the ionosphere

TABLE A.9
SCIENTIFIC MISSION SUPPORT

A. Ionospheric Measurements

- Measure transmission effects of nuclear burst simulation for DNA.
- CRRES (measure disturbance in ionosphere from chemical release from sounding rocket for NASA)

B. Crustal Dynamics for NASA

C. Small Space Debris Monitoring for NASA

- Size
- Numbers
- Orbits

D. Shuttle Tracking for NASA

E. Sea Clutter Measurements for Navy

from chemical releases from sounding rockets. Measurement requirements are very similar to those of DNA.

A.9.3 CRUSTAL DYNAMICS

NASA is using the facilities at Kwajalein along with the Haystack radar to measure plate position and motion. The facilities utilized at USAKA is a large diameter antenna (9 meters or larger) to support a dual S/X band receiver operating at 2.2 to 2.3 GHz and 8.1 to 8.6 GHz. The receiver is supplied by NASA. The antenna required needs to yield 50% or better efficiency at X-band, be able to cover the sky down to 5 degrees, and be capable of a slew rate of better than one degree per second in each axis. The system needs to have a pointing accuracy for 0.3 beamwidths at X-band (~3 arc minutes). The data collection time periods are eight one day or four two day missions per year.

A.9.4 SMALL SPACE DEBRIS MONITORING

U.S. Space Command presently maintains a catalog of more than 7000 objects in space. Most appear to be larger than about 10 cm in diameter and are in low earth orbit. Extrapolation from the tracked objects, examination of various objects returned to earth, and radar and optical debris observations result in predictions that the 7000 tracked objects represent only about 0.2% of the orbital debris population.

Small debris is normally defined as objects smaller than 10 cm in diameter. Computer simulations predict approximately 17,500 objects 1-10 cm in diameter (about 0.5% of the total population) and 3,500,000 objects smaller than 1 cm (99.3%). However, observations from optical telescopes and analysis of material retrieved from orbit are the only current empirical data sources. Data derived from these ground-based and in-space measurements reveal an increasing debris populations with decreasing debris piece size. Explosions of large objects have the

potential of producing a much larger number of smaller objects, objects too small to be detected by current space surveillance sensors.

The Space Surveillance Network (SSN), which is operated primarily by DoD, is tasked to monitor all man-made objects in space. The primary function of the SSN is to track earth orbiting objects in order to allow the missile warning radars to distinguish between orbiting and incoming missile attacks. To accomplish this task, a world-wide array of sensors has been established. The observations from these sensors are compiled into a single database and its associated document -- the Satellite Catalog. There are currently over 7,000 objects large enough to be detected, tracked, and cataloged. There are perhaps millions more objects that are too small to be detected and tracked consistently. The SSN sensors only provide positional data on the objects and a rough approximation of size. Using data from these and other sources, various characteristics about the debris are studied, including radar reflectivity, shape, mass, velocity and orbital inclination.

Figure A.1 shows the location of the SSN sensors. These sensors can be divided into two categories: 1) radars, used for detection and tracking of objects in both Low Earth Orbit (LEO) and Geosynchronous Earth Orbit (GEO) and, 2) optical, used primarily for detection and tracking of GEO objects. At GEO altitudes, the resolution of optical systems is significantly better than that of radar systems.

Figure A.2 shows the altitudes covered for each category of sensor, and the size of objects each is capable of detecting. Observations gathered from these sensors are used in developing a model of the debris environment and its behavior. This model is then used to predict various trends and measurements. As the figure illustrates, the minimum size object that can be detected is about 10 cm diameter. For a given type of sensor (radar or optical), the higher the altitude of an object the larger the object must be for the SSN sensors to track it. This limitation is significant due to the estimated large number of objects below this size threshold.

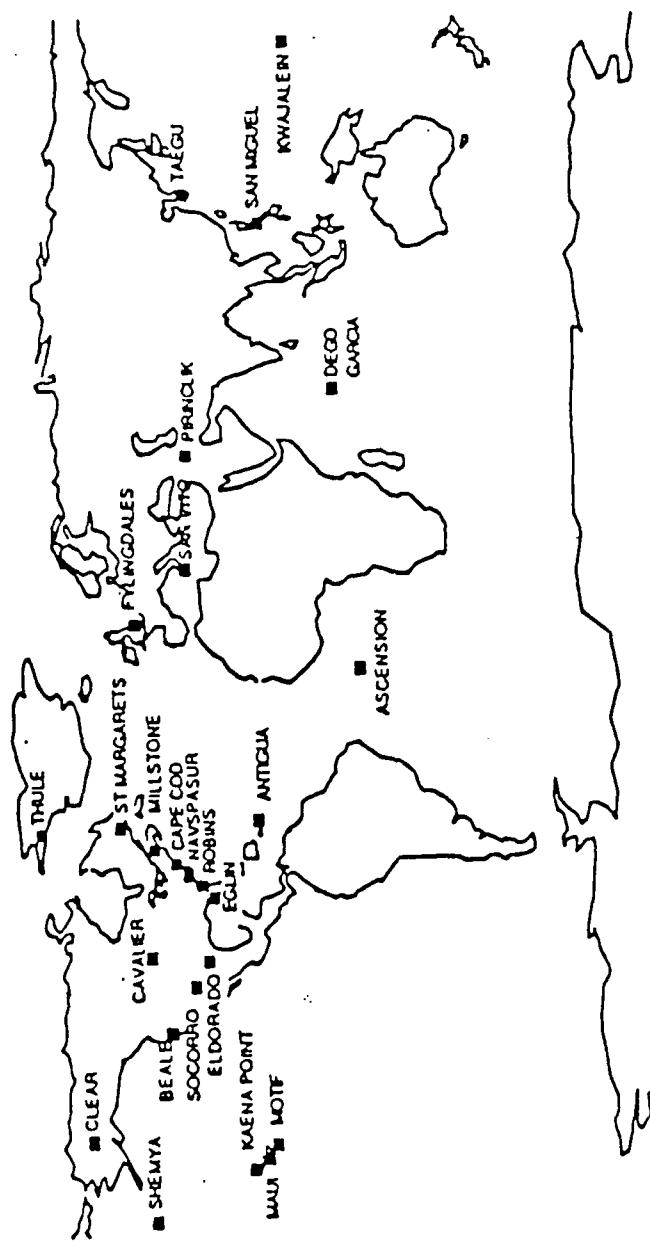


Figure A.1. Space Surveillance Network (SSN)

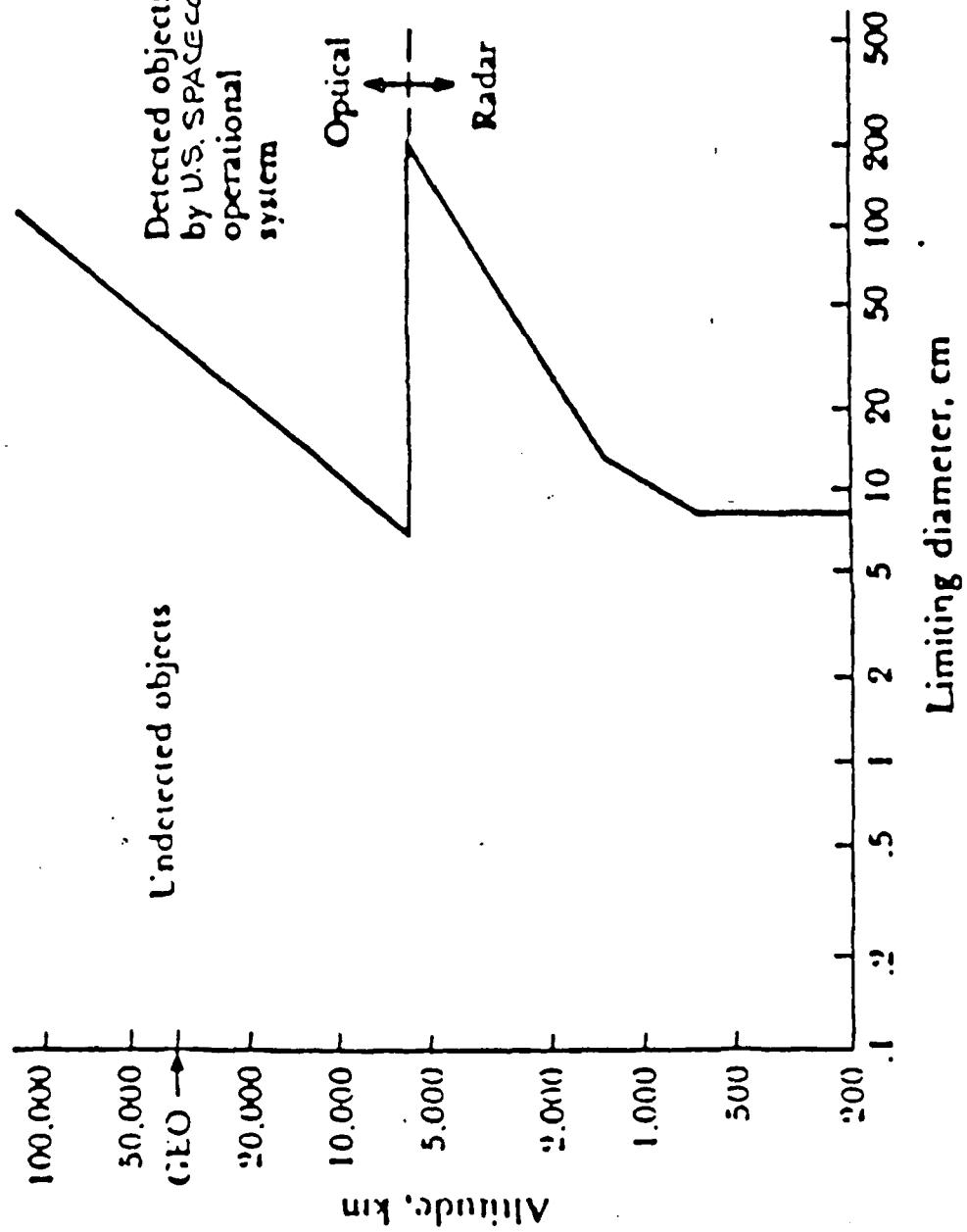


Figure A.2. Sensor Altitude Limitations

Other limitations significantly affect the SSN capability to detect and track orbital debris. The limitations due to a lack of resource availability is created by an already overtasked SSN. By employing special techniques, SSN sensors could be used to detect smaller orbital debris objects; however, these techniques involve the use of SSN sensors for extended time periods (over 4,000 hrs), which places an extreme burden on the normal SSN mission.

Because of current detection limitations, data inputs to the models are limited. The lack of data on small objects necessitates reliance on modeling of breakup events, which are a major contributor to the small debris population. Therefore, it is necessary to study breakups in detail, both experimentally and theoretically, in order to satisfactorily model the small debris environment.

Elements of the existing space surveillance sensors should begin collecting orbital debris data to the extent that primary sensor missions are not impaired. This data collection effort will support a study, the purpose of which is two-fold:

- a. To begin baselining the debris environment in low earth orbit prior to the operational capability of the Debris Environment Characterization Radar (DECR), and,
- b. To empirically assess the Space Surveillance Center's ability to process and analyze this type and quantity of data.

A.9.5 SHUTTLE TRACKING

During shuttle missions, USAKA participates in the mission support effort by tracking the satellite while it is in range of USAKA radars. This information is provided to mission control in order to ensure correct mission performance. These missions are assigned to USAKA because of their general geographic location and capabilities and are not unique system design and capability drivers.



A.9.6 SEA CLUTTER MEASUREMENTS

The Navy needs to know atmospheric transmission characteristics at very low altitude, high humidity conditions. Because the sensors at USAKA are surrounded by water, they make an ideal location for the measurement of the phenomenology of atmospheric impact on transmissions at various bands. The specific bands and ranges of interest will vary with the mission scenario supported; however, the general data collected is at several RF and optical bands.

A.10.0

SUMMARY

The users of data from the USAKA Test Facilities can be best summarized in four categories: 1) ICBM Mission-Operational Tests (A.2.0), 2) ICBM Missions-Research and Development Tests (A.3.0-A.6.0), 3) Space Surveillance and Intelligence Missions (A.7.0 and A.8.0), and 4) Scientific Experiment Support (A.9.0). In analyzing these categories, it is apparent that only the first category contains a measure of predictability and continuity in their test requirements whereas the other three categories, representing all users other than SAC, will have continuously changing and sometimes unpredictable testing needs. Does this make it impossible to define the future needs for these other users? Fortunately not, as discussed in Sections A.3.0 through A.9.0. However, it does necessitate a flexible and continuously changing test capability in order to support continuously evolving US research programs or foreign capabilities.

Some research programs such as the SDI-Directed Energy Weapons program are in such an early stage that it is not possible to define user measurement needs at this time. These programs will need to be monitored in order to begin incorporating measurement needs into USAKA plans as early as feasible.

USAKA can be viewed as having a set of fixed user needs and a set of continuously varying user needs related to changing research and development programs and evolving foreign threats. The trend in all the user categories is toward more complex test scenarios necessitating more flexible and capable test support facilities.

Tables A.10 through A.14 summarize the data used to satisfy the user requirements for the more common tests in the past. To a great extent, the data selected to use for the requirements has been based upon the sensors available. This is particularly true as planners prepare for future tests such as SDI and other special purpose tests.

TABLE A.10
USAKA USER DATA REQUIREMENTS AND QUANTIFIERS SUMMARY
(ICBM OPERATIONAL TEST-PROVEN DELIVERY SYSTEM)

TABLE A.11

USAKA USER DATA REQUIREMENTS AND QUANTIFIERS SUMMARY
(1CRM DEVELOPMENT TEST-NEW DELIVERY SYSTEM)

ENVIRONMENT	OPTICS	RF SIGNATURES (PP, OP)		SIGNATURE		IONOSPHERE	TROPOSPHERE
		WINDS & DENSITY	LID, WATER CONTENT	SWIR	MWIR		
LAUNCH CRITERIA	LWIR						
WINDS & DENSITY	UV						
LID, WATER CONTENT	VISIBILE						
SENSEUR ATTEM.	SWIR						
IONOSPHERE	MWIR						
TROPOSPHERE	LWIR						
TRAJECTORY		SIGNATURE FOR DIAGNOSTIC PURPOSES (MULTIPLE OBJECTS)		SIGNATURE FOR DIAGNOSTIC PURPOSES (MULTIPLE OBJECTS)		RCS and PULSE SHAPES	
ENDO	ENDO OPTICS						
EXO	EXO OPTICS						
DATA CATEGORIES		ENDO REALTIME S.V.		EXO REALTIME S.V.		YES	
USA KA MEASUREMENT OBJECTIVES		ENDO BEACON		EXO BEACON		YES	
EXO, Proper Deployment of Payloads		ENDO WB SKIN		EXO WB SKIN		YES	
-Object Acquisition and Count		ENDO NB SKIN		EXO NB SKIN		YES	
-Object ID		T/M		SPECIAL COM.		YES	
-Trajectory (Coarse) plus PBV		ENDO REALTIME S.V.		ENDO OPTICS		YES	
-Object ID		ENDO BEACON		EXO BEACON		YES	
-Reentry Dispersion		ENDO WB SKIN		EXO WB SKIN		YES	
-Billable Condition		ENDO NB SKIN		EXO NB SKIN		YES	
-Impact Point (Location & Time)		T/M		SPECIAL COM.		YES	
-Confirm Signature Space (RF, Optics)		ENDO, -Metric Accuracy (Fine Trajectory)		ENDO, -Metric Accuracy (Fine Trajectory)		YES	
-Confirm Signature Space (RF, Optics)		-Reentry Dispersion		-Reentry Dispersion		YES	
-Billable Condition		-Billable Condition		-Billable Condition		YES	
-Impact Point (Location & Time)		-Impact Point (Location & Time)		-Impact Point (Location & Time)		YES	
-Confirm Signature Space (RF, Optics)		-Confirm Signature Space (RF, Optics)		-Confirm Signature Space (RF, Optics)		YES	
-Body		-Body		-Body		YES	
-Wake		-Wake		-Wake		YES	
-Diagnostics		-Diagnostics		-Diagnostics		YES	
-AV Integrity		-AV Integrity		-AV Integrity		YES	
-Roll Resonance		-Roll Resonance		-Roll Resonance		YES	
-Angle of Attack		-Angle of Attack		-Angle of Attack		YES	
Convergence		Convergence		Convergence		YES	
Arming and Fusing		Arming and Fusing		Arming and Fusing		Time	

TABLE A.12

USAKA USER DATA REQUIREMENTS AND QUANTIFIERS SUMMARY
(ICBM DEVELOPMENTAL TEST PROVEN DELIVERY SYSTEM)

DATA CATEGORIES	TRAJECTORY	RF SIGNATURES (PP, OP)		OPTICS		SIGNATURE		ENVIRONMENT	
		RF	SIGNATURE	OPTICS	SIGNATURE	ENVIRONMENT	OPTICS	SIGNATURE	ENVIRONMENT
USAKA MEASUREMENT OBJECTIVES									
EXO:									
- Proper Deployment of Payloads									
- Object Acquisition and Count	RTI	YES							
- Object ID	YES	TRJ	TRJ						
- Trajectory (Course)		YES	YES						
- Payload Angular Dyn.									
- Determine Signature (RF & Optics)									
- Determine Reentry Conditions									
- Fine Motion									
- Determine Point									
- Pierce Point	YES			NO STATED ACCURACY					
ENDO:									
- Metric Accuracy					NO STATED ACCURACY				
- Reentry Dispersions	YES				NO STATED ACCURACY				
- Ballistic Coefficient	YES				NO STATED ACCURACY				
- Impact Point (Location & Time)									
TIME									
SPECIAL COM.									
T/M									
EXO WB SKIN									
EXO NB SKIN									
EXO OPTICS									
EXO REALTIME SV.									
ENDO BEACON									
ENDO WB SKIN									
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ENDO OPTICS									
EXO REALTIME SV.									
ENDO BEACON									
ENDO WB SKIN									
ENDO NB SKIN									
ENDO OPTICS									
EXO REALTIME SV.									
ENDO BEACON									

TABLE A.13

USAKA USER DATA REQUIREMENTS AND QUANTIFIERS SUMMARY

TABLE A.14

SPACE SURVEILLANCE REQUIREMENTS

DATA CATEGORIES	TRAJECTORY		RF SIGNATURES (PP, OP)		OPTICS		ENVIRONMENT	
	OPTICS	SIGNATURE	OPTICS	SIGNATURE	OPTICS	SIGNATURE	ENVIRONMENT	
US/OKA MEASUREMENT OBJECTIVES								
NEAR EARTH								
NFL DETECTION	X	X	X	X	X	X	X	
ORBIT DETERM.	X	X	X	X	X	X	X	
IDENT. (SOI)	X	X	X	X	X	X	X	
IMAGING								
DEEP SPACE								
DETECTION	X	X	X	X	X	X	X	
ORBIT DETERM.	X	X	X	X	X	X	X	
IDENT. (SOI)	X	X	X	X	X	X	X	
IMAGING								

X=Required
X'=Desired

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Mr. G. Morse, NASA/GSTC
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CAPT J. L. Sullivan, J3-S, USSPACECOM
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APPENDIX D. OPTICS STUDIES

Requirements for optical measurements at USAKA can be grouped into four categories. They are (1) Metrics, (2) Photodocumentation, (3) Reentry Signatures and Diagnostics, and (4) Exoatmospheric Measurements. Elaboration of these categories is presented in sections D.1 through D.4.

D.1 METRIC

The first category is metric measurements, where the objective is to determine the position, velocity and trajectory of an object with great precision. During reentry, the objects are very bright and can be observed even in full sunlight if a cloud free line of sight (CFLOS) is available. Sensitivity of detectors is usually not an issue and operation in the visible spectrum is both highly satisfactory and relatively economical. Technical issues usually involve sensor angular resolution and stability, pointing accuracy and precision, and operational considerations. The existing systems for this purpose are well developed. Exoatmospheric objects of the sizes and ranges of interest are also readily detected and tracked in the visible region if the objects are sunlit, but the sky is dark. Somewhat larger apertures are needed than for the reentry case, but again, the existing systems are quite well developed. The limitation of exoatmospheric tracking to sunlit object/dark sky conditions could be eliminated by operating in the LWIR. However, this would require the use of high altitude platforms and large aperture instruments for adequate sensitivity. Obtaining measurements with adequate accuracy and precision to significantly enhance trajectory data obtained with radars and during reentry would also require accurate measurement of the platform position and altitude. All of these requirements are expensive to satisfy and it has never appeared justifiable to construct such a system for metric purposes. However, if a suitable

LWIR system is needed for other purposes (see below), then it may be cost effective to incorporate metric capabilities.

D.2 PHOTODOCUMENTATION

The second category is photodocumentation. Especially when testing a new or modified system, or when failures occur, it can be difficult to determine the sequence of events occurring in a mission. While radar is extremely valuable in doing this, it still suffers from certain limitations, primarily the limited volume of space from which data is recorded, limited sensitivity to certain materials, limited time resolution, and insensitivity to certain phenomena. Optical systems can overcome many of these limitations and provide a readily interpreted record of events. While this concept originated with motion picture film cameras operating in the visible region, it has been extended to include video systems and E-O sensors operating in other wavelengths. While ground-based systems, including the metric systems, are also used for this purpose, much of this effort has been accomplished with sensors mounted on aircraft, such as the ARGUS and HALO. The aircraft are useful for several purposes:

- Obtaining a CFLOS
- Obtaining a different view angle on an event, allowing determination, for example, of vector miss distances.
- Obtaining a shorter range (providing better resolution) to events, especially during reentry and intercepts.

Non-visible wavelengths are valuable for providing insight into different temperature regimes and phenomenologies. For example, SW/MWIR are a valuable supplement to visible observations during early reentry before objects are hot enough to emit strongly in the visible. The circumstances under which the various wavelengths are usable are

similar to those previously described for metric purposes. As before, LWIR sensors would certainly be useful for photodocumentation purposes, but the cost of so doing is prohibitive for this purpose alone. Spatial/angular resolution is ordinarily more valuable in photodocumentation systems than radiometric fidelity. The concept of photodocumentation also includes a function which might be considered a separate category. This is the category of exploratory measurements. In some cases, it is unclear if a particular sort of observation might yield useful information. Such cases can sometimes be qualitatively evaluated for credibility using what are essentially photodocumentation methods in order to determine if the expected phenomena or signatures occur and if they appear to warrant the development and use of more adequate instrumentation.

D.3 REENTRY SIGNATURES AND DIAGNOSTICS

The next category is reentry signatures and diagnostics. These are used to improve the accuracy and reliability of offensive weapons, to identify and evaluate additional (especially earlier) discriminants, to evaluate vulnerabilities of offensive systems, and to evaluate solutions (e.g., penaids) to these vulnerabilities. Radiances vary enormously during reentry; in early reentry, the bodies are cold and any hot gasses are optically thin, so that radiances are essentially unchanged from the exoatmospheric regime. However, in only a few seconds, strong heating of the bodies and atmospheric gasses occurs and high radiances are produced throughout the region from the near UV through the LWIR. To date, most work has been done in this highly luminous phase of reentry, but the need for earlier discrimination has created a desire for measurements at intensities, if not ranges, more typical of the exoatmospheric phase. Complex attitudinal motions and wake turbulence produce rapid modulations of intensity; temporal resolution of these and spatial resolution of the wake is needed for some purposes. Spectroscopic measurements can be used to infer temperatures in the sheath around the vehicle, to

identify materials being ablated from it, and to infer rates of ablation. Unlike the metric and photodocumentation categories, the wavelengths used are inherent to the measurement process and not simply a matter of convenience.

D.4 EXOATMOSPHERIC

The final category of measurements is exoatmospheric. Since boost and post-boost operations are below the USAKA horizon, the observables consist of reflected sunlight, thermal emission from the objects and reflected thermal earthshine, both of the latter falling in the LL/LWIR. Because realistic resolutions imply that reflected sunlight conveys little discriminatory information relative to these objects, and because the objects may not be sunlit, interest has focussed on the L/LLWIR regions except for metric and documentation purposes. The choice of spectral bands is driven essentially by the facts that (1) a minimum of three spectral bands are required for a reasonably satisfactory determination of object temperature, emissivity, and area, and (2) three usable spectral windows are available from aircraft altitudes in the L/LLWIR region. Angular resolution to image individual objects is completely impractical, so angular resolution requirements are driven by the need to achieve certain object-to-background and object-to-clutter ratios and to separate closely spaced objects. Temporal sampling rates are driven by the need to achieve at least Nyquist sampling on objects whose rotation or tumbling rates are not more than a few Hertz. To a first approximation, the IR signal is modulated at twice the rotation/tumbling rate and the Nyquist frequency is twice the modulation frequency. Thermally large objects on ballistic missile trajectories tend to maintain interior temperatures close to those prior to launch; if their surfaces are not insulated, the surface temperatures will similarly approximate prelaunch conditions. Objects which are not thermally large or internally heated, or whose outer skins are insulated from their interiors, develop surface temperatures in equilibrium with the local

radiative environment. In sunlight, some materials, such as bare metals, become quite hot due to their high, but not perfect reflectivity in the visible and their very low emissivity in the LWIR, while materials with high LWIR emissivities tend to equilibrate at temperatures ranging from about 270K (white paints with high visible reflectivity and high LWIR emissivity; second surface mirrors; aluminized mylar) up to, say, 380K. These objects are seen against the celestial background and, except from satellite platforms, through an atmospheric background. While the atmospheric background, in the absence of clouds, is rather uniform, it is much more intense than the objects themselves (for reasonable angular resolutions). The necessity to subtract this background places significant restrictions on instrument design. The celestial background is less than the atmospheric background, but it is quite cluttered, especially in certain directions.

D.5 PLATFORMS

Platforms from which the optical measurement requirements may be satisfied is a key issue. L/LLWIR observations on midcourse objects are completely impractical from the surface at USAKA due to a combination of clouds and H₂O absorption. Both of these difficulties can be partially or wholly alleviated by moving the sensors to a platform higher in or above the atmosphere. There are essentially five types of platforms which can, conceptually, be used for this purpose. These are: (1) Aircraft, (2) Balloons, (3) Sounding Rockets ("probes"), (4) Satellites, and (5) Fly-Along packages. Advantages and disadvantages of each of these are discussed in sections D.5.1 through D.5.4. Fly-Along packages are under the control of the users and are not considered to be part of the range instrumentation.

D.5.1 Aircraft

There are many aircraft types capable of extended operation with large payloads above 40,000 ft (barometric; the corresponding true altitudes would typically be about 2,000 ft higher at USAKA), a few types capable of modest payloads above 50,000 feet, and a very few, with small payloads, above 60,000 ft. Since temperature decreases with altitude, up to the tropopause (typically 50-60 kft at USAKA), the saturation water vapor pressure also falls with altitude. Since there is essentially no water vapor above the tropopause, water vapor absorption decreases rapidly as one passes 40 kft and approaches the tropopause. With occasional exceptions, these altitudes are also well above ordinary convective clouds at USAKA. Unfortunately, there are typically two thin cloud layers above 40 kft at USAKA. The first of these is a layer of convectively generated cirrus, which typically lies at an altitude of 45 kft; the second is a layer of high altitude tropical cirrus (HATS), which typically falls somewhat above 50 kft. The frequency, density, and importance of these cloud layers are not well established and are for the moment, somewhat a matter of opinion. Fortunately, these uncertainties may be resolved as OAMP becomes operational.

It is generally agreed that dense cirrus is completely incompatible with uplooking L/LLWIR observations. However, the L/LLWIR optical density of cirrus is not well correlated with the visible cirrus density as both are strongly affected by the particle size. It is also generally agreed that dense convective cirrus is common at USAKA, that it generally occurs near 45 kft, and that its occurrence is seasonally variable, with the frequency of occurrence ranging from perhaps 40% to 70%. What is unclear is the following:

- Is the convective cirrus ever completely absent, and, if not, is it thin enough, often enough, to conduct L/LLWIR measurements through it (the success of Project Press would tend to argue that such observations are possible).

- How high must an aircraft fly to be reliably above the convective cirrus? (Aeromet has advanced a figure of 47 kft based on extensive experience).
- Is the HATS ever completely absent and, if not, is it possible to conduct L/LLWIR observations through it?
- How high must an aircraft fly in order to be reliably above this layer? This figure is conjectured by Aeromet to fall near 55 kft.
- Meteorological satellite data is clearly adequate to identify regions of dense cirrus. Is it adequate to locate the thinnest cirrus which would interfere with L/LLWIR observations?

There are certainly a variety of approaches to resolve these issues. However, at this point it would appear simplest to evaluate these questions as OAMP begins operations.

D.5.2 Balloons

Modern high altitude scientific balloons are capable of carrying sizable payloads (e.g., 10,000 lbs) to very high altitudes (into the uppermost percentile of atmospheric mass), where the only significant residual absorption would fall in the CO₂ bands. High altitude float times exceeding 24 hours are commonly achieved. The scientific community has used such balloons to accomplish a number of experiments in which large, complex and expensive payloads were carried to and operated at high altitudes and then retrieved. It is clear that balloons could be used to carry suitable L/LLWIR sensors to higher altitudes in support of USAKA measurements. Unfortunately, balloon experiments also present substantial costs and risks. The balloons themselves are expensive and fragile. Traditionally, launching has

been limited to light winds, or from the decks of ships able to match the wind velocity (an expensive proposition at USAKA). While several approaches to simplify the launching problem have been suggested, none of these has been adequately developed. The flight of balloons is also, of course, at least relatively uncontrolled. While flight paths can be predicted with moderate success, and controlled to some extent by altitude control, there is very little flexibility, since the time required to climb to float altitudes is far longer than a ballistic missile flight. Finally, although there has been considerable success in recovering balloon payloads after flight, recovery failures do occur and payload damage is not uncommon. Thus it is difficult to predicate a program on rapid turnaround of a sensor between missions. It will be seen below that several of these disadvantages are shared with probes, but for this purpose, the relative utility/cost ratio for probes and balloons appears to be in favor of probes.

D.5.3 Probes

Sounding rockets can be used to carry sensor packages above the atmosphere and permit exoatmospheric observations. While the time above the atmosphere is not large, it can be long enough (10-15 minutes) to observe the relevant portions of a ballistic missile trajectory, and even permit a period of stellar calibration prior to reentry. Reentry velocities are in the range of 3 to 6 km/second, with the result that recovery of instrument payloads is practical, if not always reliable.

Such probes have substantial advantages. The time required for a probe to pass out of the sensible atmosphere is quite short, so that it can be launched well after the targets (advantage is taken of this fact in the Queen Match); thus it is relatively tolerant to slips and scrubs of launches. The horizontal velocity of probes is typically quite low, so that viewing geometries and mission planning tend to be simple. The probe is also usually within range of ground assets so that telemetry and command are readily provided. On a given flight,

it is practical to encounter a wide range of object aspect angles and ranges, providing a broad range of signals, which are representative of different defensive scenarios. Unlike balloons and aircraft, there are no disturbing forces, so that highly accurate and stable pointing can be achieved.

There are, of course, also difficulties with probes. The most important of these are risk and cost. Payload recovery is less than absolutely certain in probe launches, and it is common for some degree of refurbishment to be required between launches, with the result that costs are high and uncertain and schedules are extended and unreliable. Additionally, the launch vehicles themselves are expensive, even if obtained as surplus from other programs and launch operations are expensive. For this reason, it has been common to conceptually pair probe measurements with aircraft measurements, so that a few probe measurements are used to validate or calibrate extensive aircraft measurements.

D.5.4 Satellites

At first glance, satellites would appear to be the ultimate platform: they are exoatmospheric and they provide extended periods of operation and experiment opportunities. In fact, satellites provide the only missions with the extended duration needed to acquire adequate background measurements. However, they are extremely expensive and require long lead time for implementation. This viability and utility will become apparent as experience is gained with MSX.

D.6 STUDY TO SATISFY USER OPTICAL DATA REQUIREMENTS

As discussed in the previous sections, several factors must be considered in selecting an optical system for data collection at Kwajalein. Chief among these are the following:

- It is difficult for a single platform type--aircraft, probe, balloon or satellite--to satisfy all USAKA L/LLWIR midcourse requirements;
- It is difficult for a single sensor system to satisfy multiple test ranges and data users (e.g., BSD, Navy, SDC, SDIO);
- The sensor platforms are, of necessity, mobile; and
- The cost of an individual L/LLWIR sensor/platform system with performance adequate for sensing midcourse objects is from perhaps one hundred million to several hundred million dollars.

It is clear that the cost of providing adequate L/LLWIR midcourse object sensing capability at USAKA exceeds funds likely to be available for that purpose alone. On the other hand, it is equally clear that the nation must develop and operate sensor/platform systems of several of the above types in order to acquire critically needed data. This must be a national effort. USAKA should be a part of the organization of a national consortium of data users and providers which would coordinate the development and operation of a national fleet of such sensor/platform systems. Such a fleet should contain aircraft, probe and satellite systems. While balloons might be used, it is not apparent that they provide non-redundant capabilities (with respect to the above platform types) or significant cost savings. Fly-along packages will, of course, also be used, but their costs are such as to not justify national-level attention; they should be left to individual users, although the consortium would be wise to maintain information on new and prior systems of this sort. It is recognized that all of the assets currently existing or under development belong to specific agencies. It is not realistic to suppose that these agencies will turn over the possession or management of these assets

to a consortium. However, we believe that it is reasonable to expect that sufficient cooperation exists such that their development and operations can be voluntarily coordinated in a manner to ensure multiple needs are satisfied.

Several issues exist regarding the utilization and suitability of the inventory of assets in existence or under development:

- This inventory consists of the OAMP, AOA/AST, EDX, and MSX systems. While the Spirit II and CIRRIS 1A systems might be added to this list, their purposes and capabilities seem sufficiently specialized that coordination would not be required.
- The principle issues involving the OAMP system are the frequency and reliability with which it will be able to operate with a CFLOS at USAKA and its inability to measure more than one object at a time. Further discussion of the first issue should await the results of flight operations to be conducted within the next year. It is our opinion, based on the data presented during this study, that cirrus clouds will present a significant, but not fatal, hindrance to the use of the OAMP at USAKA. Subsidiary issues relate to the desirability (or necessity) of providing spare or additional focal plane systems for the OAMP. Consideration should also be given to augmenting the OAMP platform with other sensors (for operational convenience) and with GPS.
- There are several major issues surrounding the AOA/AST system:
 - + When will the system be operational?

- + How frequently and reliably will it be able to operate above cirrus at USAKA (the AOA/AST does provide a significantly higher ceiling than the OAMP)?
- + The AOA/AST was not designed as a measurement sensor. While it is capable of acquiring data on a large suite of objects concurrently, the data is not expected to be of the same caliber as that provided by the OAMP, the selection of spectral bands is substantially suboptimal for midcourse objects, and the data recording system is both inadequate and inappropriate for measurement purposes.
- Every advantage should be taken of meteorological satellite data which might be used to assist the OAMP and AOA/AST platforms in finding cirrus-free regions from which to operate. The meteorological satellites in question include the US polar orbiters and geostationary satellites and the Japanese geostationary satellites. Analysis should include both retrospective analysis to identify the most promising geographic and seasonal opportunities (this has been done, at least to a first order, by MIT-LL and the University of Wisconsin, but should be reexamined in light of initial OAMP operations) and analysis of real-time (as recent as possible) data to support individual missions. Development (or adaptation) of mesoscale meteorological models for conditions at USAKA should also be undertaken.

On the other hand, the AOA/AST system offers several important advantages/opportunities which must be considered:

- + The Boeing 767 platform has a significantly higher ceiling than the C-135. It also has the capability to carry a second major (suite of) instrument(s) in the second bay of the cupola. Unloading some of the equipment needed to

support its currently planned tests would result in an increase of ceiling or at least offset the ceiling loss incurred by additional instruments. Unfortunately, the platform is the property of Boeing and its purchase might be required.

- + The focal plane is accessible and could be, if necessary, replaced with a focal plane more appropriate for measurement purposes. To what extent the multi-object tracking capability could be retained in this case is unclear. Obviously, there is a very large investment in the optics and related systems. It appears foolish to discard this investment just because the originally intended purpose for the system is no longer needed and because the focal plane intended for the purpose is inappropriate for measurement purposes. Unfortunately, the wavelength limitations of the system appear to be firmly embedded in the optics; alleviating this shortfall would presumably require substantial resources.
- + The AST platform is capable of operating directly from USAKA, affording considerably more operational flexibility.

We recommend that a part of the optical study be devoted to defining the course of future development of the AST.

- Both the MSX and EDX systems are essentially at the PDR stage, so that significant changes in these systems would be accompanied by significant cost and schedule impacts. While both of these systems appear very sound, the MSX does suffer from a significant drawback from the USAKA viewpoint in that it cannot be controlled in real time from USAKA. Principal concerns regarding these systems appear to be cost and schedule, with mirror continuation as a third issue for the

MSX. We do not recommend that, at this point, significant changes to the MSX or EDX sensors should be considered, or that additional designs should be pursued.

All of the above recommendations should be, of course, subject to review by the recommended Midcourse L/LLWIR Sensor Consortium.

Satellites also suffer from a number of constraining factors as instrument platforms.

- Cooling of L/LLWIR sensors to cryogenic temperatures is required for observations of midcourse objects. This cooling does not represent a major problem for aircraft, balloon or probe-borne sensors. However, sensor cooling is a major concern for satellite sensors. The only reasonable options for these measurements are cryogenic refrigerators and stored cryogen systems. Cryogenic refrigerators appear, at present, to still be slightly beyond the range of feasibility. So far, all satellite systems to operate in this temperature and load regime have selected stored cryogen systems. Examples include the CLAES, IRAS, COBE, MSX and Teal Ruby systems. The MSX system, which is designed for exactly these observations, uses solid hydrogen as a stored cryogen; an orbital lifetime of about 30 months is anticipated. The necessity for very low thermal impacts to the dewar forces a number of compromises on other system design elements. Generally, these tend to result in increased cost rather than lower performance. The continuing operation at low temperatures also aggravates the contamination problem.
- Orbital motion: Orbital motion presents three problems:
 - + It is possible to design satellite orbits providing satisfactory viewing of objects launched from the West

Coast to USAKA; this has been done for MSX. These opportunities can occur at any local solar time of interest and it is possible to design the orbit such that the local solar time varies over periods from a few months to several years. However, because these orbits are quite stable, the satellite can support experiments only on its predetermined schedule. This is likely to conflict with other experiment or schedule requirements. This difficulty could be largely obviated if the satellite could operate in or near geosynchronous orbit. However, L/LLWIR sensors which could perform these measurements from geosynchronous latitudes are beyond the current state-of-the-art.

- + The orbital velocity of the MSX is to be appropriately 7.4 km/sec. Similar velocities would be expected for other currently practical satellite sensor systems. Therefore, unless one accepts the very substantial launch vehicle performance penalty of a low-inclination retrograde orbit, range varies very rapidly during a satellite sensor/test object encounter. While some of the data will be acquired at short ranges, much of it will be acquired at long ranges. A corollary is that only minor slippages in launch schedules can be tolerated without at least a one orbit recycle (the MSX orbit was selected to permit both a one orbit and 24 hour recycle opportunities).
- + Because the orbit is predictable foreign launches can be scheduled to be outside of satellite viewing capability. (Orbital maneuvers are not an attractive option, due to optical contamination).
- Background Contamination - The angle between the earth limb (or horizon) and a distant midcourse object is quite small. Therefore, these sensors require very high rejection of off-

axis radiation. Achieving this rejection requires that the mirrors be extremely clean and smooth. Since the mirrors are at cryogenic temperatures, almost all spacecraft contaminants will stick to the mirrors and degrade the off-axis rejection. It is not yet clear how long the optics will remain clean, or how they can be cleaned on-orbit.

A related issue is particulate contamination. Thermal cycling of spacecraft as they pass from sunlight to eclipse results in the shedding of microscopic debris, especially paint flakes. These particles travel with the spacecraft until swept away by atmospheric or other forces. The result is that spacecraft tend to be surrounded by clouds of debris particles through which observations must be conducted. These particles will usually be out of focus and hence disrupt signals from multiple detectors.

- Cost - Given the comparative (projected) costs of the OAMP, AOA/AST, MSX, and EDX systems, it is not clear that satellite systems cost more than aircraft or probe systems. However, if one compares the number of missions and lifecycle costs of the three types of platforms, it appears that aircraft will produce the lowest cost per data set, satellites the second lowest, and probes the highest.
- Utility - Satellites provide a different range of utility than aircraft or probes:
 - + Test Objects: All three platform types can be used to obtain data on test objects launched into USAKA.
 - + Satellites: All three platform types can be used to obtain data on satellites.

- + Earth Limb Backgrounds: Aircraft cannot be used to acquire data on the earth limb background as emission is expected to primarily occur in the spectral absorption bands in which an aircraft sensor cannot see into the earth limb. Probes cannot be used to acquire a statistical data base of earth limb backgrounds, which is sorely needed, but they can be used to observe significant short-lived events, e.g., intense aurorae. Satellites can acquire the earth limb statistical data base, but are rather poorly suited for rare, short-lived events such as intense aurorae, as they are usually not in the right place when the event occurs and they fly past too rapidly to study the time evolution of the event.
- + Celestial Backgrounds: Atmospheric absorption limits aircraft observations of celestial backgrounds and observing time and cost make probes unattractive for the purpose. Satellites are ideal for this purpose, due to the lack of intervening atmosphere and availability of long observing times. Indeed, the best presently available celestial backgrounds data was obtained by IRAS.
- Windows - Balloon and aircraft sensors require the use of windows in order to prevent the condensation of atmospheric gasses on the focal plane. Such windows are not required for satellite or probe sensors. The windows have several undesirable, but not entirely unacceptable effects:
 - + Emission: The windows and external optics cannot be cooled below the highest temperature at which condensation of atmospheric gasses will occur. Since the windows have a certain (low) emissivity, this results in a background continuum which reduces contrast and increases photon noise levels.

- + Scan Noise: Windows can be a source of scan noise.
- + Absorption: Window materials compatible with other aspects of system design may have absorption limiting the spectral range of the instrument as, for example, in the AST.
- Viewing Geometry - Satellite viewing geometries are unattractive for reentry for two reasons. The first is that the objects are viewed either against or very near to the earth limb/earth disc, which presents an intense L/LLWIR background. Objects in early reentry cannot be seen against this background and good off-axis rejection is required to see them near it. The second reason is that looking at or close to the earth disc consumes cryogens very rapidly and may raise the focal plane temperature to unacceptable levels.
- Data and Sampling Rates - For several reasons, some involving the antiballistic missile treaty, it is attractive, but probably not essential, that a satellite borne measurement sensor acquire and record data on not just the test objects themselves but on the whole section of sky in which they fall. The MSX, for example, is to repetitively scan either a $1^\circ \times 3^\circ$ or $1^\circ \times 1.5^\circ$ segment of sky which will contain the test objects and backgrounds. This requirement, together with requirements for adequate dwell times on test objects, data storage, and the desire to perform TDI (if any) on the ground, rather than on board, tends to lead to designs in which the revisit times are relatively slow. The MSX, for example, will scan these scenes at $1^\circ/\text{second}$, so that the average revisit times for a particular object will be either 3 seconds or 1.5 seconds. This is far below the Nyquist sampling rate of these objects and will not allow reconstruction of their temporal behavior, only a series of snapshots.

Fly-Along Sensors

Conceptually, the simplest way to obtain L/LLWIR data on test objects is to place L/LLWIR instruments on the same vehicle as the test objects and to observe the objects from close range. Obviously this approach is not applicable to all situations, but the close ranges obtained permit the observations to be made with rather insensitive and inexpensive sensors. The signals can be telemetered back to earth or recorded on the sensor packages and recovered, although the high reentry velocities make the latter approach somewhat difficult. When the instrument packages can be made sufficiently inexpensive, this is a very attractive approach. Ordinarily, these sensors are not sufficiently sensitive to obtain useful background data.

It should be evident from the preceding discussions that no single sensor platform combination can satisfy all user requirements at USAKA or, for that matter, any other major user venue. This finding is consistent with current efforts, as the US has aircraft, probe, and satellite based L/LLWIR midcourse sensor systems either under development or in operation for exactly the reasons outlined in Appendix D. None of these sensors is intended to be dedicated to USAKA, yet all have the potential for supplying needed data for test range users.